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THORAD-AGENA ASCENT AND AGENA ORBITAL PERFORMANCE EVALUATION FOR SPACE ELECTRIC ROCKET TEST II (SERT II) MISSION

Lewis Research Center
Cleveland, Ohio 44135

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16. Abstract

A Thorad-Agena launch vehicle successfully placed the Space Electric Rocket Test II (SERT II) spacecraft onto a near-polar, "sun-synchronous", near-circular orbit at an altitude of about 1010 kilometers. The SERT II spacecraft, containing two experimental electron-bombardment mercury-ion thrusters, was part of an orbital vehicle that also included a spacecraft support unit, the Agena, and two solar arrays. The orbital vehicle was launched from Vandenberg Air Force Base, California, in February 1970. This report contains an evaluation of the Thorad-Agena systems during ascent to the proper orbit, and an evaluation of the Agena systems used for the first in-orbital support of an NASA unmanned program.

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THORAD-AGENA ASCENT AND AGENA ORBITAL PERFORMANCE EVALUATION FOR SPACE ELECTRIC ROCKET TEST II (SERT II) MISSION

Lewis Research Center

SUMMARY

The Thorad-Agena launch vehicle with the Space Electric Rocket Test II (SERT II) spacecraft was successfuly launched from the Space Launch Complex - 2 East, Vandenberg Air Force Base, California, on February 3, 1970, at 1849:49.84 hours Pacific standard time. The Thorad boosted the Agena-SERT II into a suborbital coast ellipse. After separation of the Agena-SERT II from the Thorad, the Agena engine was started and the Agena-SERT II was injected into a near-polar transfer orbit with a perigee altitude of approximately 158 kilometers and an apogee altitude of approximately 1002 kilometers. After a 48-minute coast (to near the apogee of the transfer orbit), the Agena engine was restarted and injected the 1545-kilogram orbital vehicle (consisting of the SERT II spacecraft, a spacecraft support unit, the Agena, and two solar arrays attached to the Agena) into the desired orbit. This near-polar orbit had a perigee altitude of 1011 kilometers and an apogee altitude of 1012 kilometers, with the orbit plane approximately perpendicular to the sun-earth line. Orbit parameters were such that the orbit plane would precess at about 1° per day to remain nearly perpendicular to the sun-earth line for at least 6 months (i.e., "sun synchronous"). The second cutoff of the Agena engine completed the ascent phase of the SERT II mission.

The Agena then began an orbital phase of operation that lasted for about 17 orbits. During these 17 orbits the Agena established the required configuration of the orbital vehicle (nose-down attitude with solar panels deployed), discharged Agena residual propellant, vented Agena residual attitude control gas, and transferred the operation of the Agena horizon sensors to the SERT II spacecraft. After the propellant discharge and gas venting, the orbital vehicle weighed 1434 kilograms. These Agena activities were accomplished by preprogrammed commands within the Agena, and by four ground commands transmitted to the Agena via a spacecraft command link. The last command sent to the Agena occurred on orbit 17 ($\sim 29\frac{1}{2}$ hr after launch) and terminated the Agena's active support of the orbital vehicle. Thereafter, the Agena provided passive support

to the SERT II mission as a pendulous mass for the gravity gradient - control moment gyro attitude control system, and as structural attachment for the other parts of the orbital vehicle. This was the first NASA usage of the Agena as part of an orbital vehicle for an unmanned program.

This report contain an evaluation of the Thorad-Agena systems during the ascent phase and of the Agena systems during the orbital phase of the SERT II mission.

INTRODUCTION

The purpose of the Space Electric Rocket Test II (SERT II) mission was to operate an experimental electron-bombardment mercury-ion thrustor system in a space enviroment for 6 months. For this mission, the launch vehicle objectives were twofold. First, the Thorad-Agena was required to place an orbital vehicle into a near-polar, "sun-synchronous", near-circular orbit. Second, the Agena was required to establish the proper orbital configuration (i.e., nose-down attitude, solar panels deployed, and residual propellant and residual control gas vented) and to contribute to gravity-gradient attitude control of the orbital vehicle.

The orbital vehicle was composed of the SERT II spacecraft, the spacecraft support unit (SSU), the Agena, and the solar arrays. The SERT II spacecraft containing the ion thruster system (including power conditioning equipment) was attached to the SSU; and the SSU, containing the housekeeping power system and command and telemetry equipment, was attached to the forward section of the Agena. The solar arrays, which provided electrical power to the SERT II spacecraft and SSU, were attached to the aft section of the Agena.

The SERT program has been under the direction of the Lewis Research Center. SERT I was a suborbital mission launched by a Scout vehicle from Wallops Island, Virginia, on July 20, 1964. SERT II, the only planned orbital mission, was launched from the Vandenberg Air Force Base, California, on February 3, 1970. The SERT II mission marked the first usage of the Agena as part of an orbital vehicle in support of a NASA unmanned program. The first part of this report contains an evaluation of the Thorad-Agena systems during the ascent phase and the second part contains an evaluation of the Agena systems during the in-orbit phase.

SERT II SPACE VEHICLE ASCENT PHASE

1. LAUNCH VEHICLE DESCRIPTION (ASCENT CONFIGURATION)

by Eugene E. Coffey and Rodney M. Knight

The Thorad-Agena is a two-stage launch vehicle consisting of a Thorad first stage and an Agena second stage, connected by a booster adapter. The composite vehicle (fig. 1-1) including the shroud and the booster adapter is about 33 meters (109 ft) in length. The total weight at lift-off is approximately 91 625 kilograms (202 000 lbm). Figure 1-2 shows the Thorad-Agena lift-off with SERT II.

The Thorad stage consists of a long-tank Thor and three solid-propellant rocket motors located 120° apart and attached to the long-tank Thor near the aft end. The long-tank Thor is 21.4 meters (70.3 ft) in length, and is 2.4 meters (8 ft) in diameter except for the conical forward section which tapers to a diameter of about 1.6 meters (5.3 ft). The solid-propellant rocket motors are each about 7.4 meters (24 ft) in length and are 0.8 meter (2.5 ft) in diameter with a conical forward end. The Thorad is powered by a main engine with a sea-level-rated thrust of 756×10^{3} newtons (170 000 lbf), two vernier engines with a total sea-level-rated thrust of 8.9×10^{3} newtons (2000 lbf), and the three solid-propellant rocket motors with a total sea-level-rated thrust of 696×10^{3} newtons (156 450 lbf). The propellants for the Thorad main engine and the vernier engines are liquid oxygen and high-grade kerosene. The propellant for the solid-propellant rocket motors is basically a solid grain of polybutadiene acrylic acid and ammonium perchlorate. The vernier engines, the main engine, and the solid-propellant rocket motors are ignited in sequence prior to lift-off. The fixed-nozzle, solid-propellant rocket motors burn for approximately 39 seconds. They are jettisoned at T + 102 seconds in order to assure impact of the solid-propellant rocket motor cases in a safe area (water impact). Thorad main engine cutoff occurs when the desired velocity for the planned suborbital ellipse is achieved, as determined by the radio guidance system or by propellant depletion. During powered flight the Thorad main engine gimbals for pitch and yaw control and the vernier engines gimbal for roll control. After Thorad main engine cutoff the vernier engines continue to thrust for 9 seconds to provide for vehicle attitude control and for fine trajectory corrections. After vernier engine cutoff the Thorad is severed from the Agena by the firing of a Mild Detonating Fuse located on the forward end of the booster adapter. The firing of a retrorocket system, mounted on the booster adapter, then separates the Thorad with booster adapter from the Agena.

The Agena stage is 1.5 meters (5 ft) in diameter, and the length of the Agena including the standard Agena clamshell shroud is about 12 meters (40 ft). The Agena engine has a rated vacuum thrust of 71.2×10^3 newtons (16 000 lbf). This engine uses unsymmetrical dimethylhydrazine and inhibited red fuming nitric acid as propellants. During powered flight, pitch and yaw attitude control are provided by hydraulic actuators which gimbal the Agena engine, and roll control is provided by pneumatically operated thrust valves. The pneumatic valves provide pitch, yaw, and roll control during periods of nonpowered flight. A fiber-glass laminate clamshell shroud provides environmental protection for the spacecraft during ascent. For SERT II this shroud was jettisoned 10 seconds after Agena engine first start.

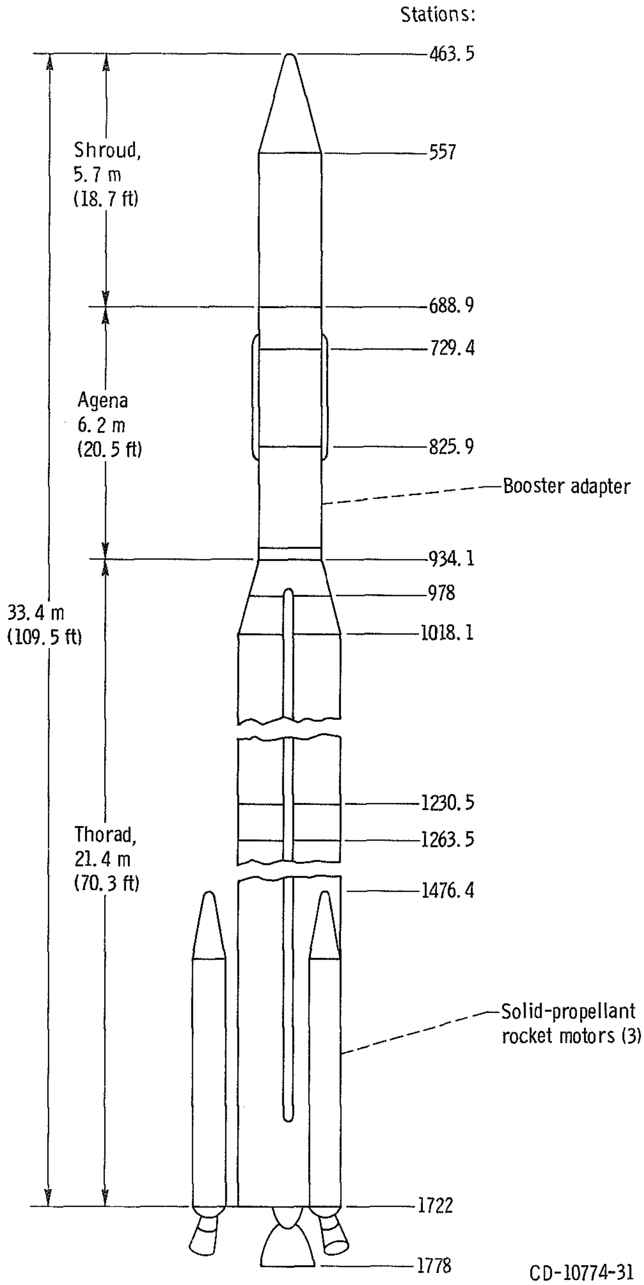


Figure 1-1. - Composite space vehicle, SERT II.

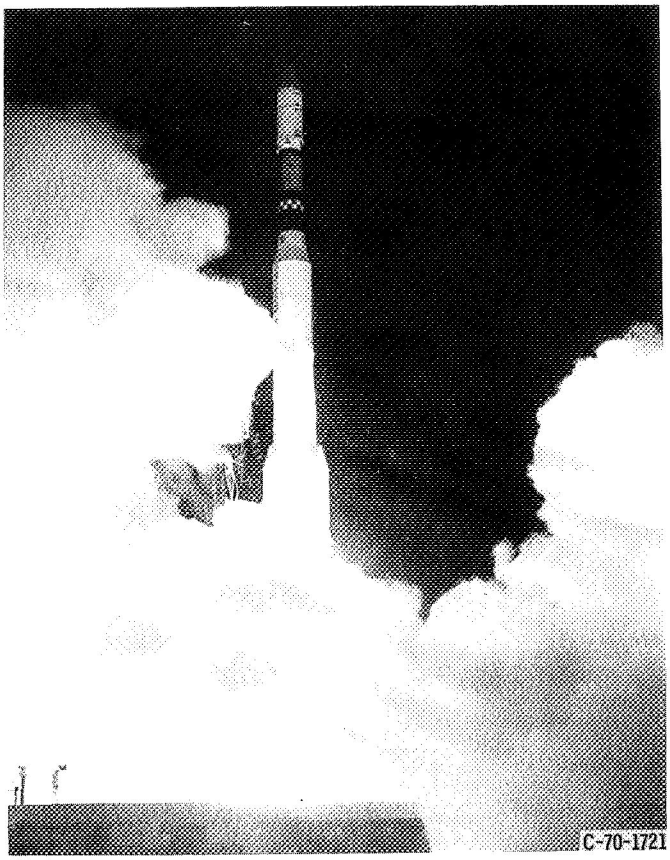


Figure 1-2. - Thorad-Agena lift-off with SERT II.

2. TRAJECTORY AND PERFORMANCE

by James C. Stoll

SERT II was successfully launched from the Space Launch Complex - 2 East, Vandenberg Air Force Base, California, on February 3, 1970, at 1849:49.84 Pacific standard time. Actual and expected times for flight events are given in appendix A.

TRAJECTORY PLAN

For the near-polar, "sun-synchronous" SERT II mission, the Thorad-Agena launch vehicle was used. The Thorad boosts the Agena-SERT II into a prescribed suborital coast ellipse. Following Thorad-Agena separation, the Agena engine is started and thrusts until it places the Agena-SERT II into an elliptical transfer orbit of 157.4 kilometers (85 n mi) perigee altitude and 1000.0 kilometers (540 n mi) apogee altitude. The Agena-SERT II then coasts to near the apogee of the elliptical transfer orbit, where the Agena engine is restarted. The Agena engine then thrusts for the second time to place the Agena-SERT II into a near-circular, "sun-synchronous" orbit at an apogee altitude of 998.2 kilometers (539 n mi) and a perigee altitude of 1014.9 kilometers (548 n mi), with an inclination of 99.10° to the equator. This completes the ascent phase of the mission. The planned ascent and initial orbit is shown in figure 2-1. The orbital phase is discussed in detail in the second part of this report.

TRAJECTORY RESULTS

Wind Aloft

The winds at launch were light and predominantly from the southwest with a peak velocity of 20.4 meters per second (67 ft/sec) from the west occurring at an altitude of 15 240 meters (50 000 ft). Wind data are shown in figure 2-2. The wind shears produced by abrupt changes in wind velocity were not severe.

The T - 0 (lift-off) weather ballon data were used to calculate the maximum vehicle bending response and the maximum gimbal angle. The maximum vehicle bending response was calculated to be 45.4 percent of the critical value at Thorad station 1341.89 and to occur at an altitude of 1535.6 meters (5038 ft). The maximum booster gimbal angle was calculated to be 27.3 percent of the total available gimbal angle in the pitch plane and to occur at an altitude of 1246.6 meters (4090 ft).

Thorad Boost Phase

Lift-off occurred from a pad azimuth of 259.5°. At T + 2.1 seconds the programmed roll maneuver to achieve the launch azimuth of 192.66° started. At T + 16.2 seconds the roll maneuver was terminated and the vehicle began to pitch downrange at the programmed pitch rates.

The three solid-propellant rocket motors burned out at about T + 38 seconds, but the solid-propellant rocket motor cases were not jettisoned until T + 102.8 seconds because of range safety considerations. At the time of jettison the actual trajectory was 1066.8 meters (3500 ft) left as compared to the predicted trajectory. This cross-range deviation was within the allowable tolerance. The deviations in altitude and range were insignificant.

The radio guidance system provided pitch and yaw steering commands to the Thorad from T + 124.6 to T + 220.08 seconds. The magnitude was moderate for the first 15 seconds of steering, and was minor thereafter. The maximum values of the integrated steering commands occurred at about T + 133 seconds, and these values were 7.2° pitch up and 10.0° yaw right.

The trajectory was designed for Thorad main engine cutoff to occur by either a radio guidance system command or propellant depletion. For this mission, main engine cutoff occurred by radio guidance system command at T + 223.92 seconds, 1.22 seconds later than predicted. At this time the actual trajectory was about 2438.4 meters (8000 ft) downrange, 350.5 meters (1150 ft) high, and 2545.1 meters (8350 ft) left as compared to the predicted trajectory. Also, at main engine cutoff the velocity of the vehicle was about 12.2 meters per second (40 ft/sec) lower than expected. These deviations were within tolerance. The lower-than-expected velocity coupled with the higher-than-expected vehicle position at main engine cutoff gave the proper energy for the suborbital coast ellipse.

The Thorad vernier engine thrust was terminated by a time-delay relay 9 seconds after main engine cutoff. The insertion parameters at vernier engine cutoff are listed in table 2-1 and the resulting coast ellipse parameters are listed in table 2-2. The Thorad-Agena separation was commanded by the radio guidance system at T + 239.96 seconds. The performance of the Thorad was satisfactory.

Agena First Powered Phase

After Thorad-Agena separation the Agena performed a pitch-down maneuver to place the vehicle in the proper attitude for the Agena engine first start. The Agena engine was started at T + 258.94 seconds, and 90 percent chamber pressure was achieved 1.23 seconds later. Thrust duration (measured from 90 percent chamber pressure to velocity meter cutoff) was 232.12 seconds, 0.57 second longer than predicted. The radio guidance system issued small pitch and yaw steering commands between T + 273.47 seconds and T + 390.80 seconds. The radio guidance system issued the command to enable the velocity meter at T + 392.56 seconds. The velocity meter than commanded Agena engine cutoff (when the proper velocity increment set in the velocity meter had been gained) at T + 492.29 seconds. Thrust decay added 8.2 meters per second (26.9 ft/sec) compared to a predicted 6.5 meters per second (21.2 ft/sec). The injection parameters at Agena engine first cutoff are listed in table 2-3. The Agena-SERT II transfer orbit parameters are listed in table 2-4.

Agena Second Powered Phase

The Agena-SERT II coasted for 2865.69 seconds to near the apogee of the elliptical transfer orbit. At this time (T + 3357.98 sec) the Agena engine was restarted, and 90 percent chamber pressure was achieved 1.08 seconds later. Thrust duration (measured from 90 percent chamber pressure to velocity meter cutoff) was 4.64 seconds, 0.13 second less than the expected value. Agena engine cutoff by the velocity meter at T + 3363.70 seconds indicated that the proper velocity increment had been gained. Thrust decay added 13.08 meters per second (42.9 ft/sec) compared to a predicted 12.16 meters per second (39.9 ft/sec). The injection parameters at Agena engine second cutoff are listed in table 2-5. The final orbit parameters are listed in table 2-6. Agena activities after the second powered phase (i.e., in-orbit phase) are presented in detail in the second part of this report.

TABLE 2-1. - INSERTION PARAMETERS AT VERNIER ENGINE CUTOFF, SERT II

Parameter	Units	Actual
Altitude	km	104.03
	n mi	56.17
Radius	km	6476.09
	n mi	3496.81
Velocity	m/sec	3936.79
	ft/sec	12 915.98
Inclination	deg	96.399
Azimuth	deg	187.57
Flightpath angle	deg	12.493

TABLE 2-2. - SUBORBITAL COAST ELLIPSE PARAMETERS AT APOGEE, SERT II

Parameter	Units	Actual
Altitude	km	153.27
	n mi	82.76
Radius	km	6526.63
	n mi	3524.10
Velocity	m/sec	3813.8
	ft/sec	12 512.5
Inclination	deg	96.399
Eccentricity	-----	.76184

TABLE 2-3. - INJECTION PARAMETERS AT AGENA ENGINE FIRST CUTOFF, SERT II

Parameter	Units	Actual
Altitude	km	157.98
	n mi	85.30
Radius	km	6533.54
	n mi	3527.83
Velocity	m/sec	8045.29
	ft/sec	26 395.3
Inclination	deg	99.13
Flightpath angle	deg	.103

TABLE 2-4. - TRANSFER ORBIT PARAMETERS, SERT II

Parameter	Units	Actual
Apogee radius	km	7377.24
	n mi	3983.39
Apogee altitude	km	1002.06
	n mi	541.07
Perigee radius	km	6533.37
	n mi	3527.74
Perigee altitude	km	158.31
	n mi	85.48
Period	min	96.224
Inclination	deg	99.125
Eccentricity	----	.6066

TABLE 2-5. - INJECTION PARAMETERS

AT AGENA ENGINE SECOND

CUTOFF, SERT II

Parameter	Units	Actual
Altitude	km n mi	1001.95 541.01
Radius	km n mi	7377.22 3983.38
Velocity	m/sec ft/sec	7351.85 24 120.24
Inclination	deg	99.120
Flightpath angle	deg	-.033

TABLE 2-6. - FINAL ORBIT

PARAMETERS, SERT II

Parameter	Units	Actual
Apogee altitude	km n mi	1011.62 546.23
Apogee radius	km n mi	7384.02 3987.05
Perigee altitude	km n mi	1010.93 545.86
Perigee radius	km n mi	7370.29 3979.64
Period	min	105.132
Inclination	deg	99.119
Eccentricity	----	.0009

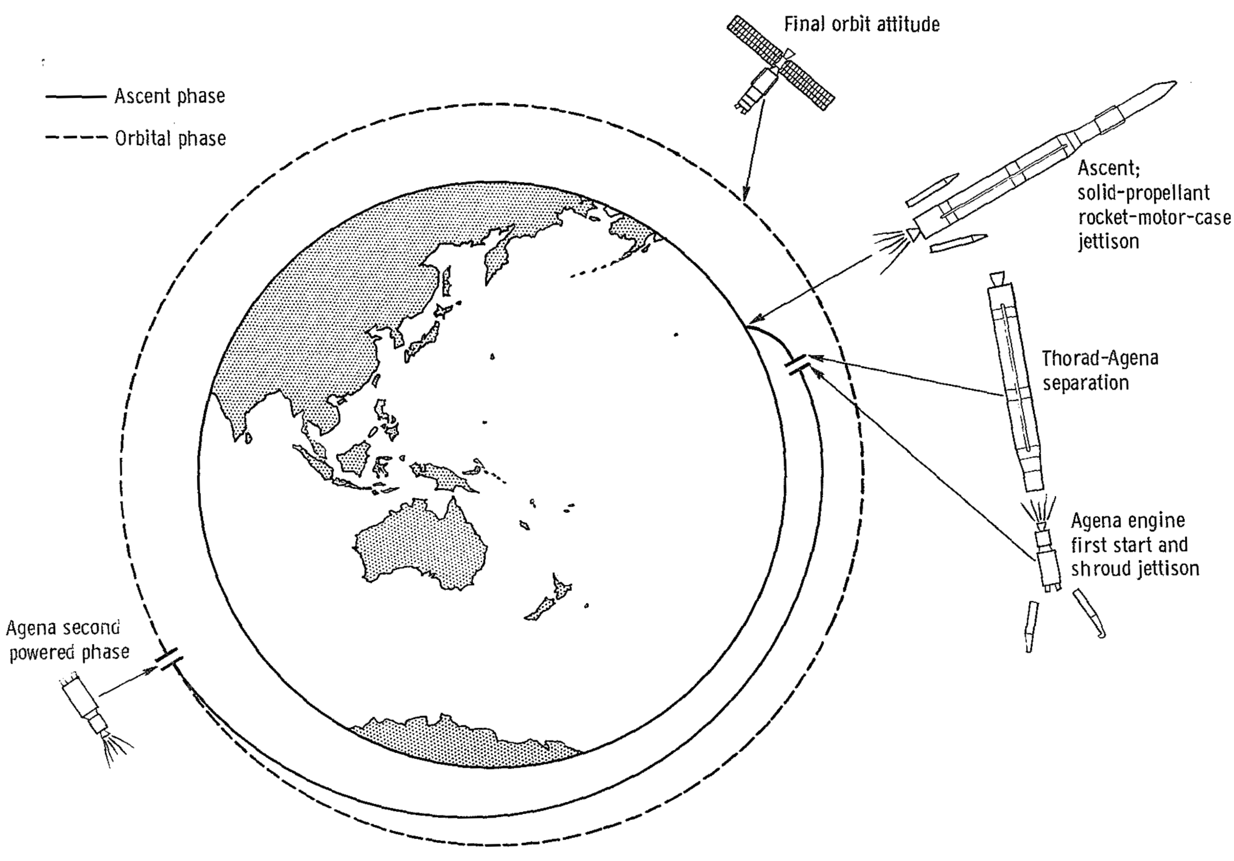


Figure 2-1. - Planned ascent and initial orbit, SERT II.

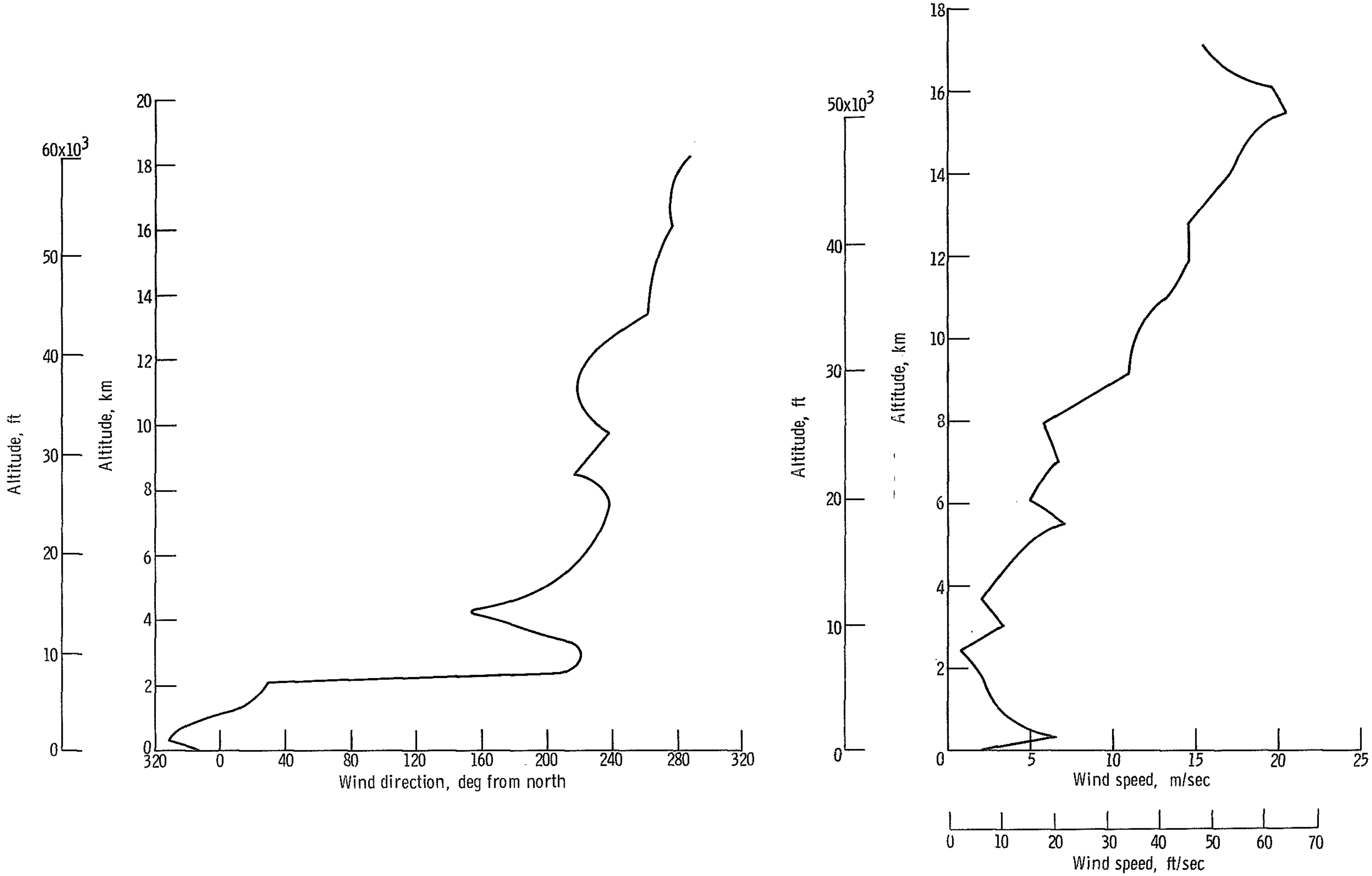


Figure 2-2. - Wind data, SERT II.

3. THORAD VEHICLE SYSTEM PERFORMANCE

VEHICLE STRUCTURE SYSTEM

by Daniel Bachkin

System Description

The Thorad airframe structure (fig. 3-1) consists of the transition section, the adapter section, the fuel tank, the centerbody section, the oxidizer tank, the aft skirt section, and the engine-and-accessories section. The Thorad is 21.4 meters (70.3 ft) in length and 2.4 meters (8 ft) in diameter except for the conical forward section which tapers to a diameter of about 1.6 meters (5.3 ft).

The transition section at the forward end of the Thorad is 1.1 meters (3.7 ft) long and consists of a truncated cone of semimonocoque construction. The transition section houses the flight control equipment, electrical power components, umbilical connection assembly, and flight termination equipment. Access doors are provided for inspection and replacement of equipment.

The adapter section, also a truncated cone, is 1.0 meter (3.3 ft) long and connects the transition section to the fuel tank.

The fuel tank assembly is 5.4 meters (17.7 ft) long and is longitudinally butt-welded to form a cylinder from three sheets of 0.63-centimeter (0.25-in.) aluminum which are milled on the interior surface in a waffle-like pattern to obtain the maximum strength/weight ratio. The fuel tank has convex domes at either end, intermediate frames, circumferential and antivortex baffles, and a fuel transfer tube and sump. The convex domes are bolted to the cylinder and have small welds to seal the joints.

The centerbody section, a semimonocoque construction is 0.8 meter (2.7 ft) long and contains the Thorad telemetry equipment. Doors are provided for access to this section.

The oxidizer tank assembly, 8.6 meters (28.2 ft) long, is similar in construction to the fuel tank assembly.

The aft skirt section is 0.9 meter (2.8 ft) long and contains the nitrogen pressurization tanks and associated components and the oxidizer fill valve.

The engine-and-accessories section, 2.2 meters (7.1 ft) long, is a semimonocoque aluminum construction with stringers and formers. The main engine is attached through a gimbal block and tripod structure to three uniformly spaced thrust beams. These beams transmit the engine thrust loads to the booster structure. While the vehicle is on the launcher, the three thrust beams and three launch beams support the vehicle. All the liquid propulsion support equipment, such as the turbopump, lubrication unit, gas generator, hydraulic unit, engine relay boxes, integrated-start airborne system, and the fuel fill valve, are housed in this section. Three solid-propellant rocket motors are attached to the thrust beams.

System Performance

The structure system performance was satisfactory and all flight loads were within the design limits. The peak longitudinal steady-state load of 6.21 g's occurred at Thorad main engine cutoff.

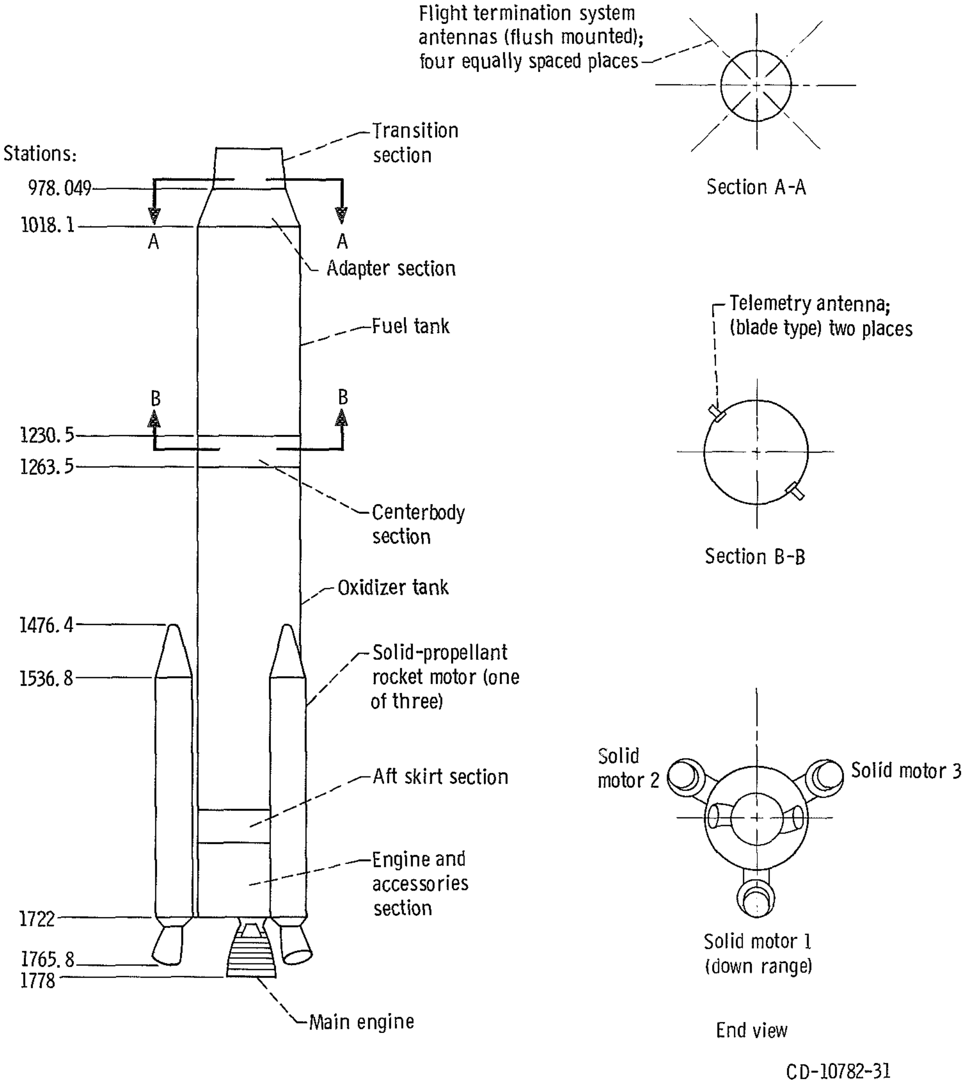


Figure 3-1. - Thorad general configuration, SERT II.

PROPULSION SYSTEM

by Daniel Bachkin

System Description

The Thorad propulsion system is composed of a liquid-propellant engine system (fig. 3-2) and three solid-propellant rocket motors.

The liquid-propellant engine system consists of a main engine, two vernier engines, and an engine start system. These engines use liquid oxygen and RJ-1 (kerosene) for propellants. During the engine start sequence, electrically initiated pyrotechnic igniters are used to ignite gas generator propellants for driving a turbopump assembly, and hypergolic igniters are used to ignite the propellants in the thrust chambers of the main and vernier engines. The pneumatic control of the liquid-propellant engine system is discussed in the next section.

The Thorad main engine, rated at 756×10^3 newtons (170 000 lbf) thrust at sea level, consists of a gimbaled thrust chamber, propellant valves, a turbopump assembly driven by a gas generator, a fuel additive blender unit (FABU) system, and a heat exchanger. The FABU system provides a lubricant supply to the gear case of the turbopump assembly by utilizing fuel (from the fuel pump volute) mixed with lubricant additive contained in the FABU. Fixed-area orifices regulate the propellant flow to the thrust chamber and to the gas generator. There is no thrust control system to compensate for changes in propellant head pressures to the pump inlets.

Each gimbaled vernier engine is rated at 4.45×10^3 newtons (1000 lbf) thrust at sea level with propellants supplied from the main engine turbopump assembly. Because the turbopump assembly does not operate after main engine cutoff, the vernier engines are supplied with propellants from the engine start tanks during the vernier solo phase of flight. For this phase, each vernier engine is rated at 3.68×10^3 newtons (830 lbf) thrust at sea level. The duration of the vernier engine solo phase is controlled by a time-delay relay that starts at main engine cutoff and provides the vernier engine cutoff command 9 seconds later.

The engine start system consists of two small propellant tanks and a pressurization system. These engine start tanks have a volume of approximately 0.028 cubic meter (1 ft^3) each and are filled and pressurized prior to launch to supply propellants for engine start. They remain pressurized and are refilled during flight to provide propellants for vernier engine operation after main engine cutoff.

The propellant grain for the three solid-propellant rocket motors is basically polybutadiene acrylic acid and ammonium perchlorate. Each solid-propellant rocket motor is rated at 232×10^3 newtons (52 150 lbf) thrust at sea level. These motors are ignited by a signal from a pressure switch on the Thorad main engine thrust chamber. This switch actuates when the chamber pressure in the Thorad main engine reaches approximately 258 N/cm^2 (375 psi) during the main engine start sequence. These solid-propellant rocket motors provide thrust for about 39 seconds and the cases are jettisoned 102 seconds after ignition. The primary jettison command is provided by a timer that starts at solid-propellant rocket motor ignition. These motors are mounted 120^o apart on the Thorad engine-and-accessories section and have an 11^o nozzle cant angle (see fig. 3-1).

System Performance

The performance of the Thorad propulsion system for the SERT II mission was satisfactory. During the liquid-propellant engine start phase, engine valve opening times and starting sequence events were within tolerances. Performance parameters, for the solid-propellant rocket motors and for the liquid-propellant engines, were normal, as indicated by a comparison of measured with expected values. These data are tabulated in table 3-1. The solid-propellant rocket motors burned for 38.3 seconds (average of the three) and the solid-propellant rocket motor cases were jettisoned at 102.8 seconds as planned.

Shortly before main engine cutoff, as on previous Thorad flights, there was a coupling of the propulsion system response characteristics with the first longitudinal mode of the vehicle structure (i.e., "POGO" effect) from T + 206 to T + 223 seconds. Within this period, from T + 211 to T + 221 seconds, the main engine chamber pressure exhibited a maximum 30-N/cm^2 (44-psi) peak-to-peak oscillation. These values are typical for POGO effect. (See Section 4 - VEHICLE STRUCTURE SYSTEM for maximum POGO acceleration levels.)

Main engine cutoff was initiated by radio guidance system command just prior to oxidizer depletion. Vernier engine cutoff occurred 9.07 seconds after main engine cutoff. Transients were normal at solid-propellant rocket motor burnout and during shutdown of the Thorad main and vernier engines.

TABLE 3-1. - THORAD PROPULSION SYSTEM PERFORMANCE, SERT II

(a) Solid-propellant rocket motors

Performance parameter	Units	Flight values at-					
		T + 10 sec		T + 25 sec		T + 35 sec	
		Expected	Measured	Expected	Measured	Expected	Measured
Combustion chamber pressure, absolute:							
Motor 1	N/cm^2	403	409	491	497	454	467
	psi	585	594	712	722	658	678
Motor 2	N/cm^2	403	400	491	492	454	453
	psi	585	580	712	715	658	658
Motor 3	N/cm^2	403	399	491	485	454	458
	psi	585	578	712	703	658	665

(b) Liquid-propellant engines

Performance parameter	Units	Flight values at-					
		T + 30 sec		Main engine cutoff		Vernier engine cutoff	
		Expected	Measured	Expected	Measured	Expected	Measured
Main engine thrust chamber pressure, absolute	N/cm^2	412	413	371	375	---	---
	psi	599	600	539	545	---	---
Turbopump speed	rpm	6232	6201	5864	5858	---	---
Vernier engine 2 thrust chamber pressure when pump supplied,[a] absolute	N/cm^2	262	263	248	241	---	---
	psi	381	385	345	350	---	---
Vernier engine 2 thrust chamber pressure when tank supplied,[a] absolute	N/cm^2	---	---	---	---	208	212
	psi	---	---	---	---	302	307

[a]Vernier engine 1 was not instrumented.

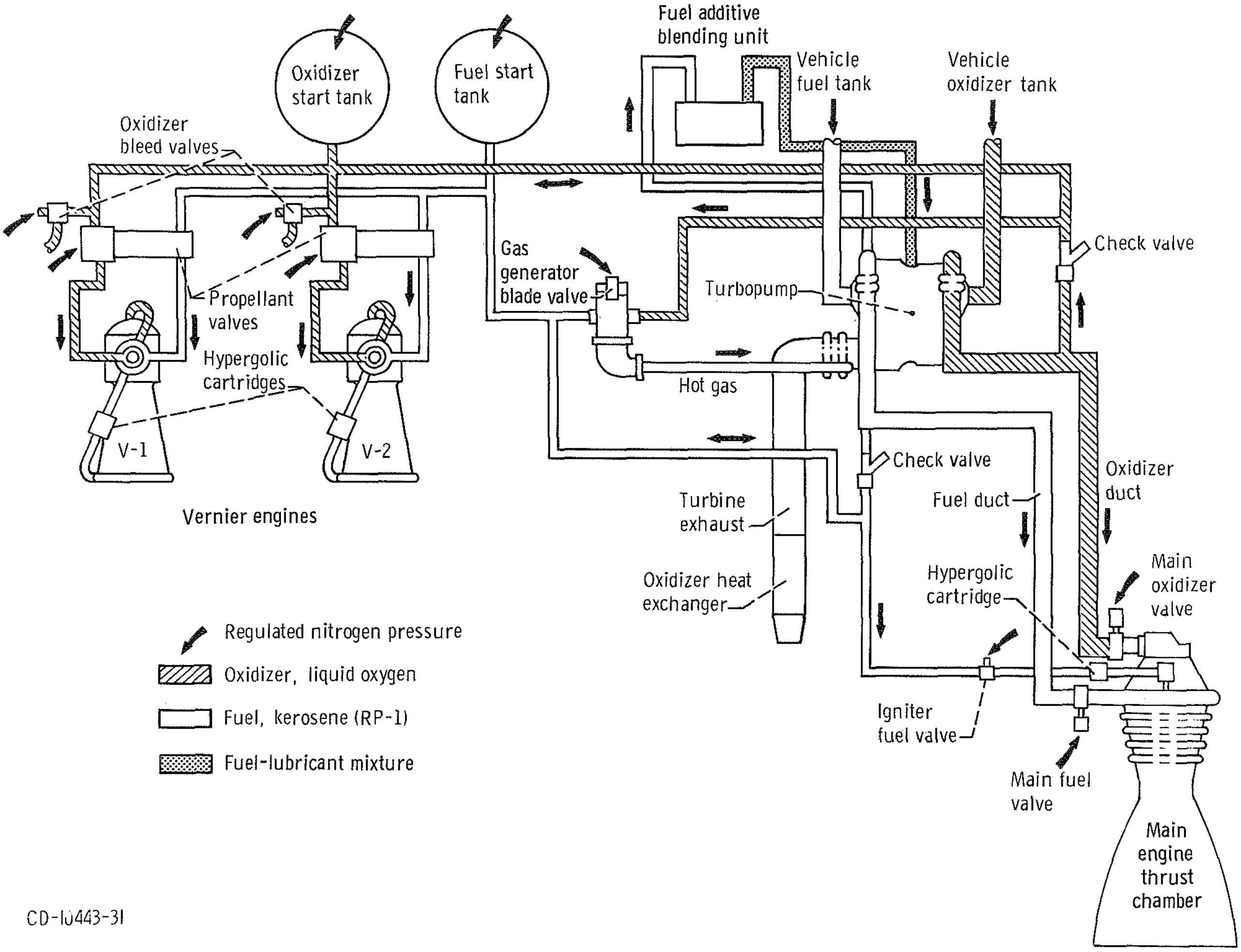


Figure 3-2. - Liquid-propellant engine system, SERT II.

PNEUMATIC SYSTEM

by Daniel Bachkin

System Description

The Thorad pneumatic system consists of the pneumatic control subsystem and the main fuel tank pressurization subsystem. High-pressure gaseous nitrogen is stored in four airborne spherical tanks to supply pressure for the airborne pneumatic system. A check valve in the system assures that one of these tanks will be restricted to providing nitrogen gas for the operation of the various functions of the pneumatic control subsystem. The three remaining tanks provide nitrogen gas for pressurizing the fuel tank and, if required, provide nitrogen gas for operation of the pneumatic control subsystem.

The pneumatic control subsystem regulates gaseous nitrogen pressure for pressurization of the engine start subsystem and the liquid-oxygen pump seal cavity and for the actuation of propellant valves. The system consists of a pneumatic control package, a filter, two solenoid control valves, and the required fittings and connecting tubing. One of the solenoid control valves controls pneumatic pressure to the main oxidizer valve. The other solenoid control valve controls pneumatic pressure to the main fuel valve and to the gas generator blade valve.

The main fuel tank pressurization subsystem bleeds high-pressure gaseous nitrogen through a fixed-area orifice to maintain the fuel tank ullage absolute pressure between 8.3 and 33.9 N/cm^2 (12 and 49 psi) during flight.

A heat exchanger in the main engine gas generator exhaust system is used to convert liquid oxygen to gaseous oxygen to maintain the oxidizer ullage pressure between 22.1 and 42.1 N/cm^2 (32 and 61 psi) during flight.

System Performance

The Thorad pneumatic system performed satisfactorily. All pneumatic system parameters and propellant tank ullage pressures observed were satisfactory. System flight performance data are presented in table 3-2.

TABLE 3-2. - THORAD PNEUMATIC SYSTEM AND TANK PRESSURIZATION

SYSTEM PERFORMANCE, SERT II

Pressure, absolute	Units	Normal range[a]	Flight values at-						
			T - 10 sec	T - 0 sec	T + 10 sec	T + 60 sec	T + 120 sec	Main engine cutoff	Vernier engine cutoff
Main fuel tank ullage pressure	N/cm^2	8.3 to 33.9	28.2	27.2	21.7	15.2	12.4	8.9	8.9
	psi	12 to 49	41	39.5	31.5	22	18	13	13
Main liquid-oxygen tank ullage pressure	N/cm^2	22.1 to 42.1	31	27.9	24.1	24.8	22.8	22.1	22.1
	psi	32 to 61	45	40.5	35	36	33	32	32
Pneumatic control tank pressure	N/cm^2	1665 to 2206	2070	2000	1960	1960	1960	1890	1040
	psi	2400 to 3200	3010	2900	2850	2850	2850	2750	[b]1510

[a]Normal values apply only during main engine operation.

[b]Pressure change from main engine cutoff to vernier engine cutoff reflects use of nitrogen for pressurization of start tanks during vernier engine solo operation as well as for pneumatic control system operation.

HYDRAULIC SYSTEM

by Russell A. Corso

System Description

The Thorad hydraulic system provides the required hydraulic power to actuators for gimbaling the main engine and the two vernier engines during flight. The hydraulic system consists of a hydraulic pump, a hydraulic accessory unit, and six actuator assemblies.

The hydraulic pump, a constant displacement pump which is driven by the turbopump accessory drive shaft, provides the required hydraulic fluid flow rate and pressure. The pump delivers 0.015 cubic meter per minute at 2206 N/cm^2 (4 gpm at 3200 psi).

The hydraulic accessory unit is located in the engine and accessory section and it contains the hydraulic system reservoir, an accumulator, filters, a check valve, a high-pressure relief valve, and three low-pressure relief valves. The high-pressure relief valve diverts flow to the reservoir when flow is not required by the actuators. The low-pressure relief valves are located in the vehicle overboard vent lines. The accumulator, which is charged with nitrogen gas during ground operations, provides a high-pressure fluid source for gimbaling the vernier engines during the vernier engine solo operation after main engine shutdown.

Two linear actuator assemblies are provided for each of the three liquid-propellant rocket engines. Each assembly consists of a servovalve, a feedback potentiometer, and a double-ended piston actuator. The servovalve directs the flow and controls the flow rate of fluid to the actuator for engine gimballing. The feedback potentiometer provides a feedback control signal to the servovalve.

System Performance

The hydraulic system functioned satisfactorily before lift-off and throughout the Thorad flight. The pressure data (supply and return) indicated that the hydraulic pressures were maintained at satisfactory levels during main engine operation and during vernier engine solo operation. Hydraulic pressure depletion occurred 27.6 seconds after vernier engine cutoff.

The hydraulic system flight performance data are presented in table 3-3.

TABLE 3-3. - THORAD HYDRAULIC SYSTEM PERFORMANCE, SERT II

	Supply pressure		Return pressure	
	N/cm^2	psia	N/cm^2	psia
Before engine ignition	2079	3015	68.9	100
Normal range during main engine operation	2068 to 2344	3000 to 3400	31 to 62	45 to 90
Flight time, sec:				
T + 20	2224	3225	40.0	58.0
T + 60	2230	3235	56.5	82.0
T + 160	2196	3185	55.2	80.0
T + 223.92 (main engine cutoff)	2151	3120	56.5	82.0
After main engine cutoff, T + 232.99 (vernier engine cutoff)	[a]1889	[a]2740	57.9	84.0

[a]Hydraulic supply pressure normally decays during vernier engine solo phase and continues to decay until pressure depletion.

GUIDANCE AND FLIGHT CONTROL SYSTEM

by Edwin S. Jeris and James L. Swavely

The Thorad flightpath is controlled by two interrelated systems: the Thorad flight control system and the radio guidance system. The flight control system directs the vehicle in a preprogrammed mode from lift-off through vernier engine cutoff. The radio guidance system will provide, if needed, pitch and yaw steering commands during approximately the last half of the Thorad powered flight. These steering commands provide corrections for vehicle deviations from the desired trajectory. The radio guidance system also provides discrete commands for Thorad main engine cutoff and Thorad-Agena separation. The radio guidance system's use during the Agena phase of flight is discussed in Section 4 - GUIDANCE AND FLIGHT CONTROL SYSTEM.

System Description

The major components of the Thorad flight control system are the control electronic assembly and three rate gyros. The control electronic assembly contains a programmer, three displacement gyros, and associated electronic circuitry. These displacement gyros are single-degree-of-freedom, floated, hermetically sealed rate-integrating gyros. These gyros are mounted in an orthogonal configuration alining the input axis of each gyro to its respective vehicle axis of pitch, yaw, or roll. Each gyro provides an electrical output signal proportional to the difference in angular position of the measured axis from the gyro input (reference) axis.

The programmer supplies discrete commands to start and stop the fixed roll program and fixed pitch program, to arm solid-propellant rocket-motor-case jettison and also provides a backup for this jettison, to enable Thorad radio guidance system steering, to enable vernier engine yaw control, to change steering gains, and to enable main engine cutoff. The programmer uses a motor-driven prepunched tape. Slots in the prepunched tape activate relay circuits for the programmer commands. For this mission the capability of the Thorad flight control system to accept radio guidance system pitch and yaw steering commands is enabled at T + 124 seconds. Between T + 124 seconds and vernier engine cutoff, all radio guidance system pitch and yaw steering commands are routed to the Thorad flight control system.

The rate gyros are of the single-degree-of-freedom, spring-restrained type. The roll-rate gyro is located in the centerbody section with the gyro input axis alined to the vehicle roll axis. The pitch- and yaw-rate gyros are located adjacent to the fuel tank in a cable tunnel with the gyro input axes alined to the vehicle pitch and yaw axes. Each rate gyro provides an electrical output signal proportional to the angular rate of rotation of the vehicle about the gyro input (reference) axis.

The radio guidance system includes airborne equipment located in the Agena (a radar transponder and command receiver, a control package, two antennas, a directional coupler, and connecting wave guide) and ground-based equipment (a radar tracking station, and a computer). The major functions (fig. 3-3) are described in the following paragraphs:

The radar tracking station transmits a composite message-train containing an address code and the steering and discrete commands to the vehicle. The radar transponder and command receiver in the Agena receives the message-train and transmits a return pulse to the ground each time the address code is correct. The radar tracking station determines vehicle position (range, azimuth, and elevation) from the return pulses. The computer processes the position information, computes trajectory corrections, and issues appropriate steering and discrete commands which are transmitted to the Agena by the radar tracking station, as described above. The steering and discrete commands are routed from the Agena to the Thorad through vehicle harnesses.

A dorsal and a ventral antenna are mounted on the forward section of the Agena and are connected through the wave guide and the directional coupler to the radar transponder and command receiver. The location of the radar tracking station antenna with respect to the launch site is such that for prelaunch testing and early ascent, the dorsal antenna provides the greater signal strength to the ground antenna. As the vehicle pitches over and moves downrange, the ventral antenna provides the greater signal strength. The directional coupler attenuates the signal from the dorsal antenna to minimize interference effects between the dorsal and ventral antennas. Mission trajectory information determines the antenna configuration, the antenna orientation, and the type of directional coupler for each mission.

During the early portion of flight, multipath and ground clutter effects might cause the radar tracking station to acquire (lock on) a false vehicle position. To avoid this problem the following procedure is used for radar tracking station acquisition (lock on) of the vehicle. Before lift-off the centerline of the ground radar antenna beam is manually pointed at the junction of the ground antenna horizon and the programmed trajectory. At lift-off a ground timer is started which will close the ground radar angle tracking loops and the range loop at T + 6 seconds, the time at which the vehicle is predicted to fly through the radar beam. When the angle and range loops are closed, the acquisition (lock on) is complete and the radar tracking station will track the actual vehicle position.

As a backup to the timer, the radar tracking station operator manually closes the angle tracking and range loops 7 seconds after lift-off. If the radar tracking station still does not acquire the launch vehicle, the ground antenna is slewed to 20 mils elevation angle to acquire at T + 11.4 seconds; then if required it is manually slewed through planned series of pointing coordinates until acquisition is effected. These coordinates correspond to first a 40-mil elevation (T + 14.3 sec) and then to the expected vehicle positions at T + 30, T + 50, and T + 70 seconds.

Frequency lock is accomplished before lift-off.

System Performance

The Thorad flight control system performed satisfactorily throughout the flight. Lift-off transients in pitch, yaw, and roll were negligible.

Maximum angular displacements of the vehicle, after radio guidance system steering was enabled, were 3.0° pitch down and 1.9° yaw right. Gimbal angles at main engine cutoff (T + 223.92 sec) were 0.4° pitch down and 0.1° yaw left. Angular displacements of the vehicle at vernier engine cutoff (T + 232.99 sec), when the Agena gyros were uncaged, were 0.1° pitch down, 0° yaw, and 0.28° clockwise roll. These angular displacements were within the allowable limits and provided a satisfactory reference attitude for the Agena. Angular rates at Thorad-Agena separation (T + 239.96 sec) were 0.2-degree-per-second pitch down, 0.1-degree-per-second yaw left, and 0.5-degree-per-second clockwise roll. Longitudinal oscillations (POGO effect) were encountered between T + 206 and T + 223 seconds. The oscillations were not detrimental to the control system performance.

The radio guidance system, ground and airborne, performed satisfactorily throughout the guided portion of flight. The frequency loop of the radar tracking station was locked on the vehicle before lift-off. Signal strength at the radar tracking station before lift-off was satisfactory. The ground-angle-loop and range-loop timer started at lift-off and actuated at T + 6 seconds. The angle and range loops were closed and vehicle acquisition (lock on) occurred at T + 6 seconds. The manual-backup for the angle loop was closed at T + 7 seconds. The signal strength at the radar tracking station was satisfactory throughout flight. Signal strength fluctuations occurred, as expected, during the two-antenna interference region from T + 35 to T + 75 seconds, when the received signal strengths from the dorsal and ventral antennas were within 10 decibels of each other. A second period of similar interference occurred briefly from T + 128 to T + 138 seconds. This unexpected second interference region was caused by vehicle response to initial steering and did not adversely affect the proper functioning of the radio guidance system. Radar tracking station data indicated the actual vehicle position was continuously tracked throughout the flight except for momentary radar coast periods during the two-antenna signal-interference regions. The performance of the ground-based computer was satisfactory throughout the countdown and vehicle flight.

Prior to lift-off the airborne radio guidance system equipment indicated a received signal strength of -14 decibels referenced to 1 milliwatt (dBm). The maximum received signal strength was -1 dBm at T + 104 seconds and decreased to -33 dBm by T + 490 seconds. The signal strength received by the vehicle throughout the flight was adequate for the operation of the radio guidance system.

All radio guidance system commands were satisfactorily generated by the computer, transmitted by the radar tracking station, and received and executed by the vehicle. Table 3-4 shows planned and actual times of all radio guidance system commands.

TABLE 3-4. - RADIO GUIDANCE SYSTEM COMMANDS, SERT II

Command	Planned time from lift-off, sec	Actual time from lift-off, sec
Thorad steering (pitch and yaw):		
Commenced	124.6	124.46
Terminated	217.9	220.08
Thorad main engine cutoff	221.6	223.92
Thorad-Agena separation[a]	237.2	239.96
Agena steering (pitch and yaw)[a]:		
Commenced	268.2	273.47
Terminated	387.0	390.80
Agena velocity meter enable[a]	388.6	392.56

[a]Commands to the Agena vehicle are discussed in Section 4 - GUIDANCE AND FLIGHT CONTROL.

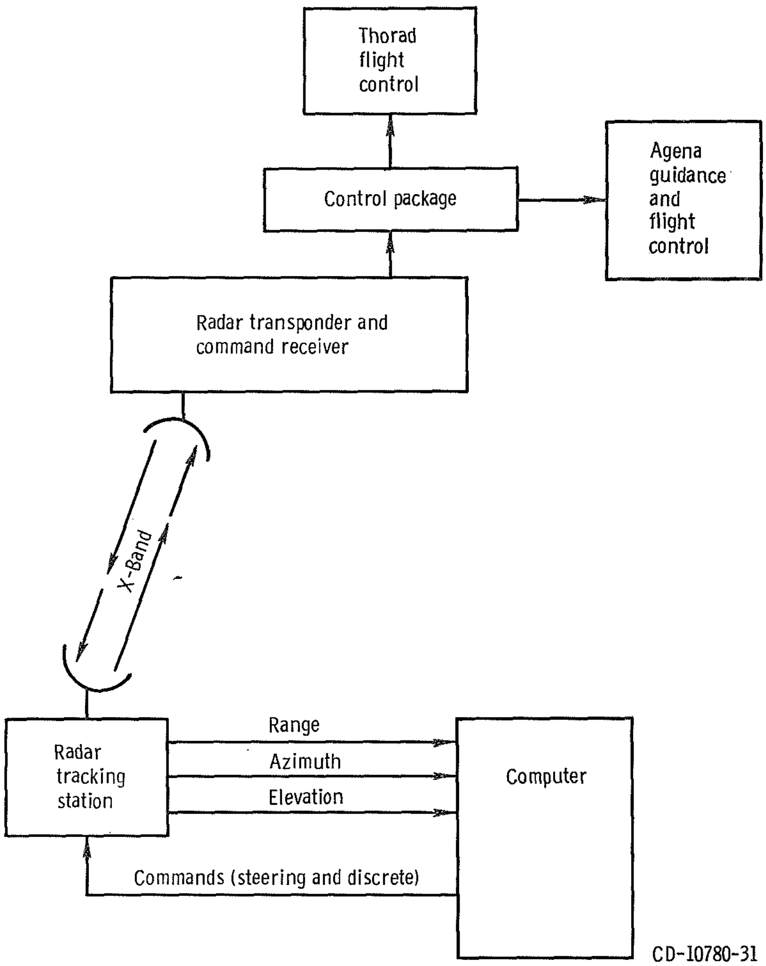


Figure 3-3. - Block diagram of major functions of the radio guidance system, SERT II.

ELECTRICAL SYSTEM

by Baxter L. Beaton

System Description

The Thorad power requirements are supplied by three 28-volt silver-zinc alkaline batteries and a 400-hertz rotary inverter (see fig. 3-4). Distribution boxes are located throughout the vehicle for interconnection and switching of electrical functions. Two tunnels located external to the propellant tanks are used to route cables between the transition, centerbody, and engine-and-accessory sections.

The main battery is rated at 20 ampere-hours and supplies all the vehicle power requirements except for the telemetry system and the flight termination system. The power requirements for these systems are supplied by the two other batteries. The telemetry battery, rated at 3 ampere-hours, supplies the telemetry system and the flight termination subsystem 1 power requirements. The remaining battery, rated at 1 ampere-hour, supplies power to flight termination subsystem 2.

The rotary inverter (a dc motor-driven ac alternator) provides the 400-hertz 115/208-volt ac, three-phase power. The voltage output and frequency of the inverter are regulated to ±1.5 percent. The alternator is wye-connected with a grounded neutral.

System Performance

The main battery supplied the requirements of the dependent systems at normal voltage levels. The battery voltage was 29.8 volts dc throughout flight. The telemetry battery (for the telemetry system and flight termination subsystem 1) voltage was between 28.6 and 28.9 volts dc during the Thorad flight. The battery which supplies power to flight termination subsystem 2 was not monitored. The rotary inverter operated within the ±1.5 percent voltage and frequency tolerance throughout the Thorad flight. The inverter frequency was 399.1 hertz at lift-off and increased to 400.3 hertz by Thorad main engine cutoff. The inverter voltage was 114.9 volts ac at lift-off and increased to 115.3 volts ac by Thorad main engine cutoff.

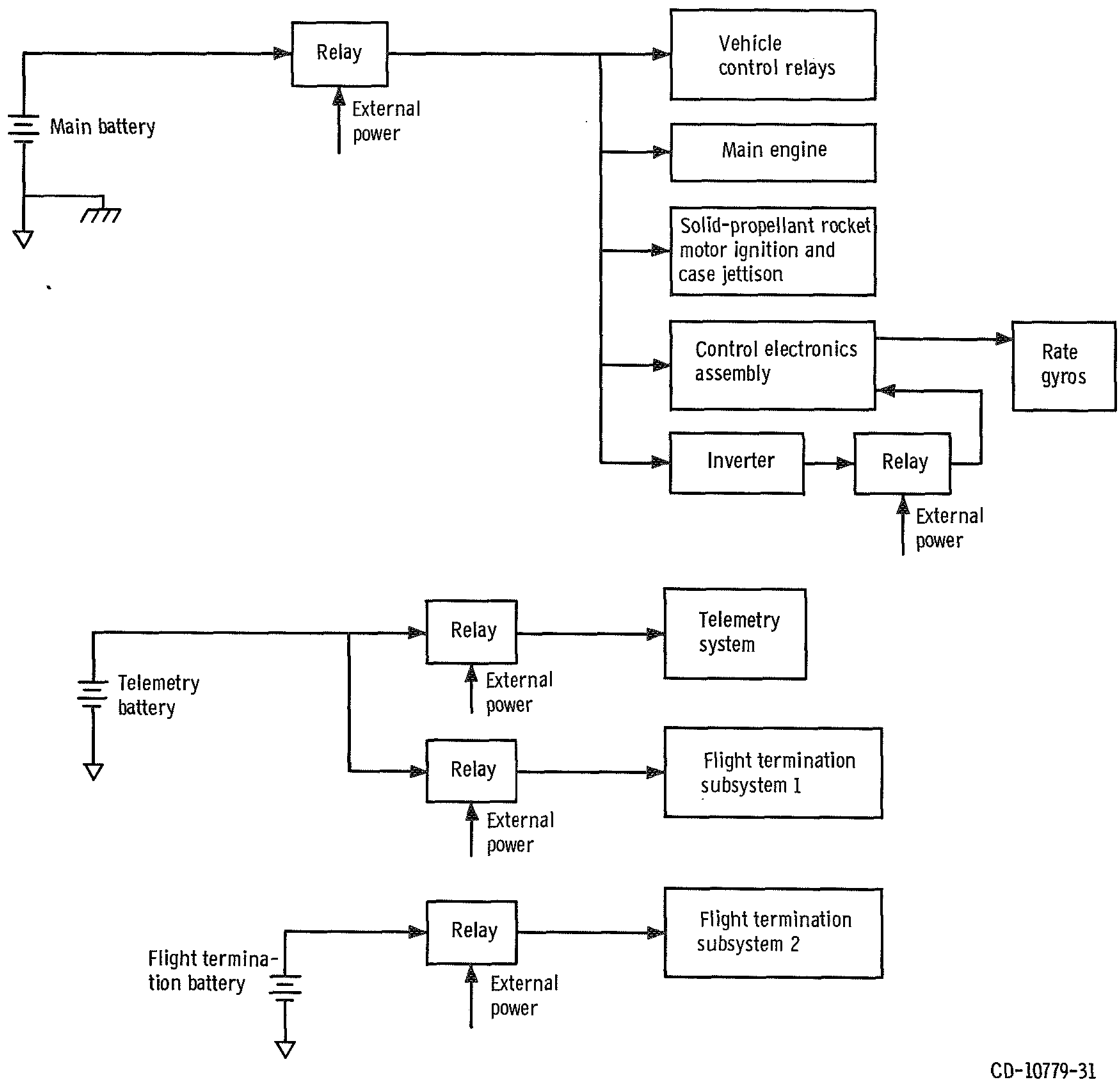


Figure 3-4. - Block diagram of Thorad power distribution system, SERT II.

TELEMETRY SYSTEM

by Richard E. Orzechowski

System Description

The Thorad telemetry system consists of two antennas, a frequency-modulated (FM) transmitter, signal conditioning circuitry, transducers, a 28-volt battery, and a multicoder. The telemetry system is located in the centerbody section. The transmitter operates on a frequency of 246.3 megahertz at a power output of 10 watts. The multicoder provides pulse duration modulation (PDM) of 43 commutated data channels to one FM subcarrier channel. Ten other FM subcarrier channels provide continuous data.

A total of 53 measurements are telemetered from the Thorad vehicle. Appendix B summarizes the launch vehicle instrumentation by measurement.

System Performance

Thorad telemetry performance for the SERT II mission was satisfactory. All 53 measurements (appendix B) yielded usable data. Radiofrequency signal strength was adequate, the carrier frequency was stable, and good quality data were provided during flight. No direct measurements of telemetry system performance or system environment were made. Appendix C (fig. C-2) shows the coverage provided by the supporting telemetry stations.

FLIGHT TERMINATION SYSTEM

by Richard E. Orzechowski

System Description

The Thorad flight termination system (fig. 3-5) consists of two identical and redundant subsystems designed to destroy the vehicle on receipt of ground command signals. Each subsystem includes two antennas (located on opposite sides of the Thorad), a command receiver, a safe-arm mechanism, and destructor cords. The antenna locations are shown on figure 3-1. The safe-arm mechanisms are armed by lanyards at lift-off. After lift-off the range safety officer can command destruction, if required, by transmitting a coded signal to the command receivers. Each command receiver will supply an electrical signal to two detonators in a Thorad safe-arm mechanism and, prior to Thorad-Agena separation, to a detonator in the Agena destruct initiator. Either detonator on a safe-arm mechanism will initiate the two destructor cords (one on each side of the Thorad propellant tanks) and, through other destructor cords, will initiate a shaped charge on the forward end of each solid-propellant rocket motor. A 0.1-second time delay in the Thorad safe-arm mechanisms ensures that the Agena destruct initiator receives the destruct signal before the Thorad is destroyed.

The Agena destruct components are discussed in Section 4 - COMMUNICATION AND CONTROL SYSTEM.

System Performance

Both command receivers in the Thorad flight termination system functioned satisfactorily during flight. The data indicated that the vehicle received adequate signal strength for the operation of each flight termination subsystem and that the signal level remained essentially constant throughout the period in which destruct capability was required. No flight termination commands were required, nor were any commands inadvertently generated by any vehicle system.

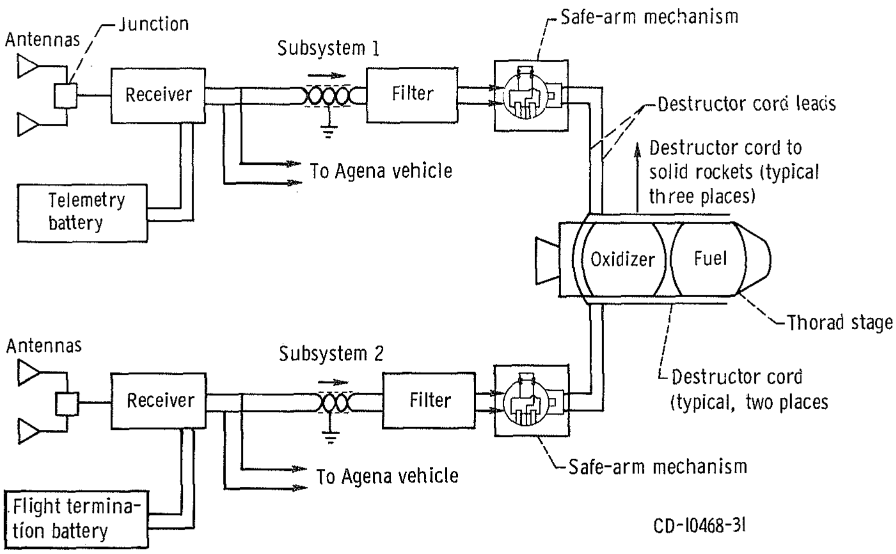


Figure 3-5. - Thorad flight termination system, SERT II.

4. AGENA VEHICLE SYSTEM PERFORMANCE

VEHICLE STRUCTURE SYSTEM

by C. Robert Finkelstein

System Description

The Agena vehicle structure system (fig. 4-1) consists of four major sections: the forward section, the propellant tank section, the aft section, and the booster adapter section. Together they provide the aerodynamic shape, structural support, and environmental protection for the vehicle. The forward section is basically an aluminum structure with beryllium and magnesium panels. This section encloses most of the electrical, guidance, and communication equipment and provides the mechanical and electrical interface for the spacecraft support unit (SSU) and the shroud. The propellant tank section consists of two integral aluminum tanks with a sump below each tank to assure a supply of propellants for engine starts in a zero-gravity environment. The aft section consists of an engine mounting cone structure and equipment mounting rack. The booster adapter section is a magnesium alloy structure and remains with the Thorad after Thorad-Agena separation.

For SERT II, two solar arrays (described in Section 6: THE ORITAL VEHICLE) were mounted on the equipment mounting rack of the Agena aft section. The Agena structure was modified to carry increased loads during ascent, by adding skin panels to the engine mounting cone. Solar array support structures were added to the equipment mounting rack. Brackets to support two thermal shields were also attached to the equipment mounting rack. The two thermal shields protected the solar arrays from the heat of the Agena engine (see fig. 4-1).

System Performance

The measured dynamic environment of the structure system was within design limits. The maximum measured combined longitudinal load (steady state plus vibrational) on the structural system was 8.75 g's. This load resulted from superimposing a 3.84-g, zero-to-peak, vibrational load (frequency, 17.2 Hz) on a 4.91-g, steady-state load. This maximum load occurred at T + 211.0 seconds, during the Thorad POGO oscillations. Significant dynamic load data are presented in appendix D.

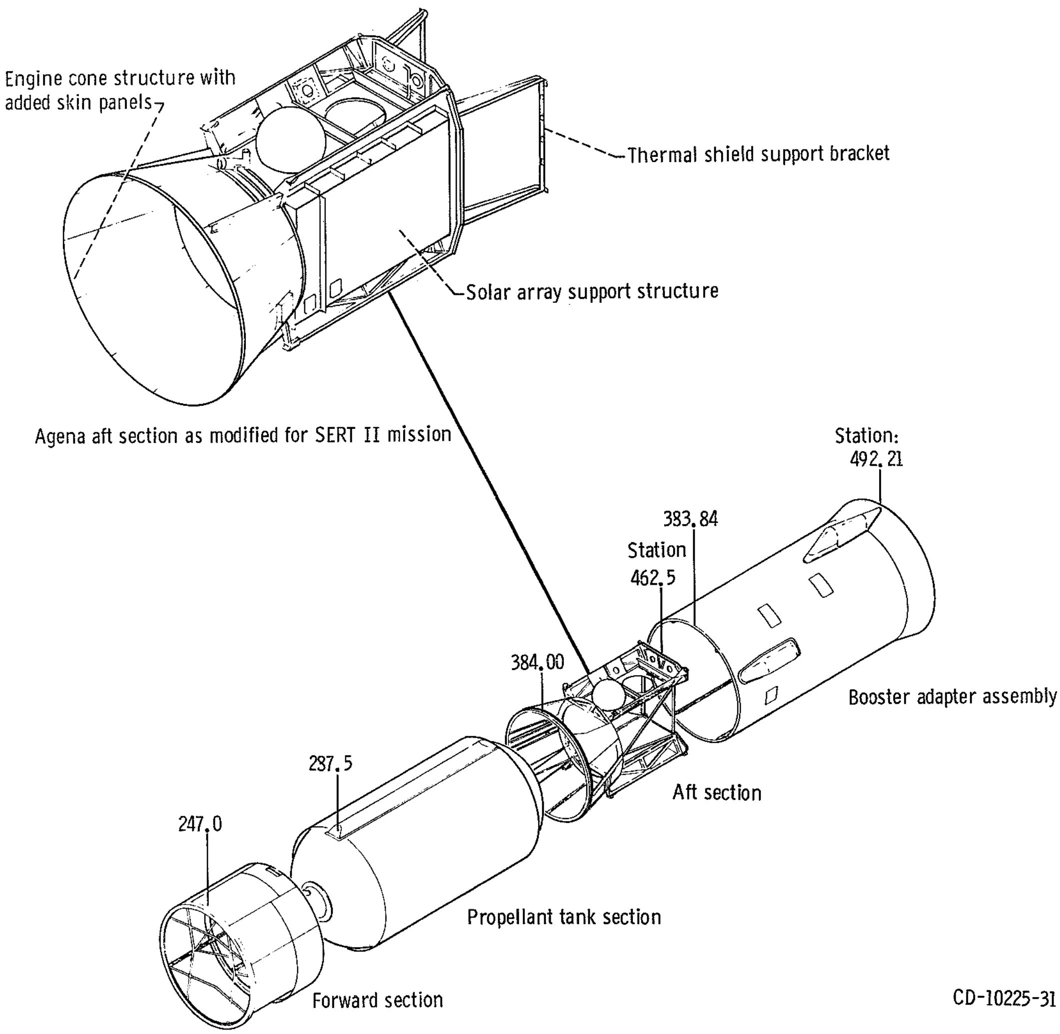


Figure 4-1. - Agena vehicle structure system, SERT II.

SHROUD SYSTEM

by C. Robert Finkelstein

System Description

The shroud system is the standard Agena clamshell (SAC) shroud with minor mission modifications incorporated. The shroud provides environmental protection for the spacecraft prior to launch and during ascent. The SAC shroud, shown in figure 4-2, is 5.72 meters (18.78 ft) long and weighs 327.33 kilograms (721 lbm). It consists of an aluminum transition ring and two shroud halves. These two shroud halves form a fairing with a 1.65-meter (5.42-ft) diameter cylindrical section, a 15° half-angle conical section, and a 0.61-meter (2 ft) diameter, hemispherical nose cap. The shroud halves are constructed of laminated fiber glass strengthened by internally attached aluminum semicircular frames, and an aluminum longeron along each split line. Microquartz thermal insulation blankets in the cylindrical section of each shroud half and a foil covering in the conical section of each half provide thermal protection for the spacecraft. Each shroud half is equipped with two teflon-coated magnesium skid pads which guide and protect the spring-loaded antennas on the spacecraft support unit (SSU) during shroud jettison. The skid pads extend from approximately station 244.6 to station 219.1 and are attached to the inside surface of the shroud halves. The shroud halves are held together by a nose bolt assembly, two flat bands around the cylindrical section, and a V-band around the base of the cylindrical section. The top and middle flat bands and the V-band are tensioned to 22 250, 11 570, and 35 600 newtons (5000, 2600, and 8000 lbf), respectively.

The transition ring, approximately 5.1 centimeters (2 in.) high, is bolted to two half-rings attached to the forward end of the Agena. The spacecraft support unit (SSU) is bolted to the transition ring and the spacecraft is bolted to the SSU. The shroud is clamped to the transition ring by the V-band mentioned previously. A metal diaphragm, attached to the transition ring, isolates the shroud cavity from the Agena. During ascent, this cavity is vented through four ports in the cylindrical section of the shroud. These ports, which are equipped with flappers, permit venting in an outward direction only.

Shroud jettison is commanded by the Agena timer 10 seconds after Agena engine first start. At this time, Agena electrical power fires squibs which actuate two pyrotechnic boltcutters in the nose bolt assembly and two explosive bolts in each of the three bands. The operation of at least one boltcutter in the nose bolt assembly and one bolt in each of the bands is required for shroud release. Two pairs of springs in each shroud half thrust against the transition ring and provide the energy to rotate each shroud half about hinges mounted on the transition ring. At the time of shroud jettison, the Agena has a longitudinal acceleration of approximately 1 g. At this acceleration level, each shroud half rotates through an angle of about 75^{o} before it leaves the hinges and falls free. The shroud separation springs have enough energy to successfully jettison the shroud halves at vehicle (Agena) longitudinal acceleration levels as high as 3.5 g's.

The shroud system is instrumented for measurement of the differential pressure across the shroud diaphragm.

System Performance

Shroud pyrotechnics were fired at T + 268.95 seconds and the shroud was satisfactorily jettisoned. At this time the vehicle roll rate and yaw rate were very nearly zero, and the pitch rate was at the programmed geocentric value. Shroud jettison did not measurably affect Agena roll, yaw, or pitch rates. The diaphragm differential pressure transducer did not produce usuable data. (See Section 4 - COMMUNICATION AND CONTROL SYSTEM for discussion of this instrumentation anomaly.)

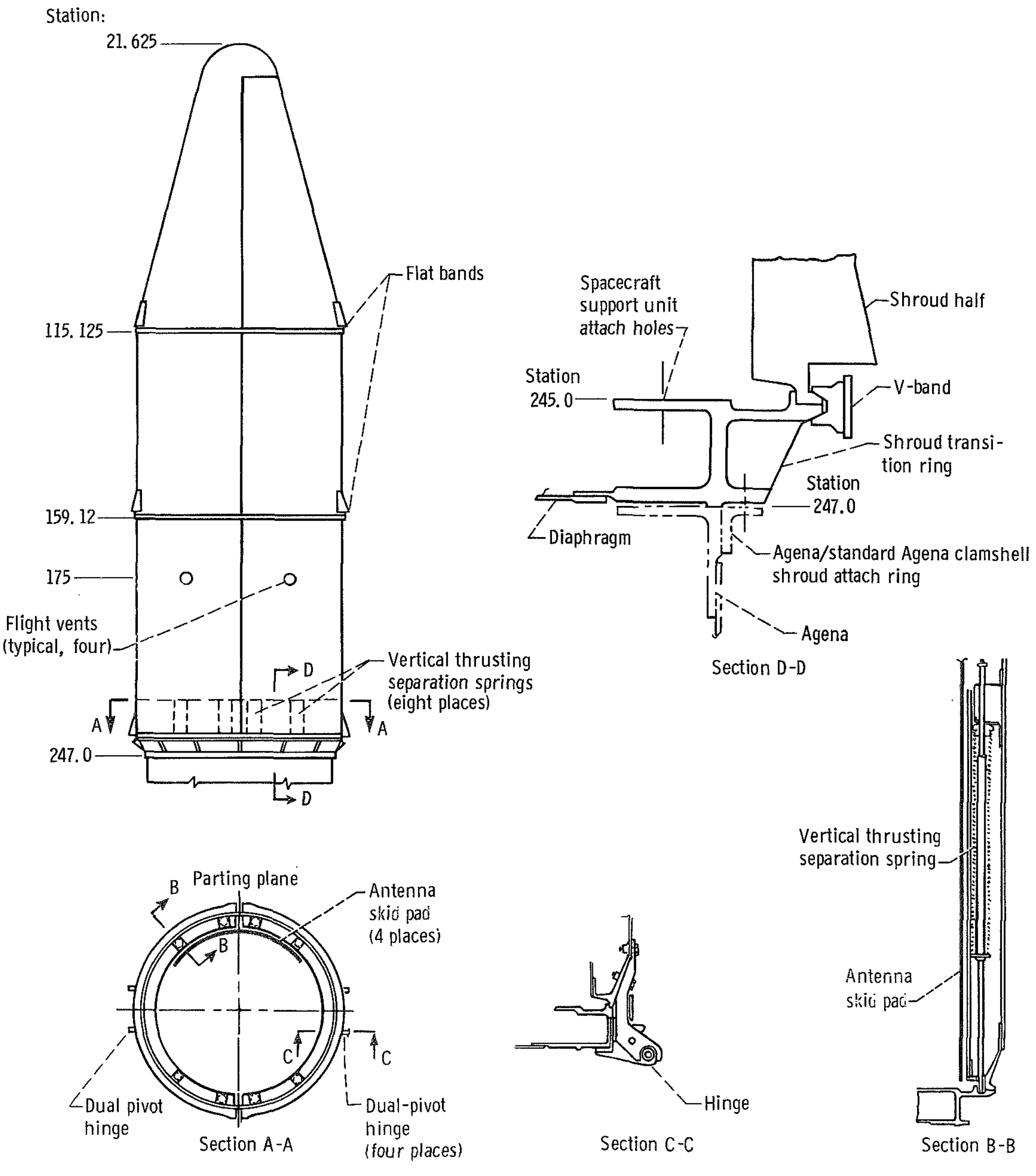


Figure 4-2. - Standard Agena clamshell shroud, SERT II.

PROPULSION SYSTEM

by Robert J. Schroeder

System Description

The Agena propulsion system (fig. 4-3) consists of a propellant tank pressurization system, a propellant management system, and an engine system. Also considered part of the propulsion system are the Thorad-Agena separation system and the Agena vehicle pyrotechnic devices.

The propellant tank pressurization system provides the required propellant tank pressures and consists of a helium supply tank and a pyrotechnically operated helium control valve. Before lift-off the ullage volume in the propellant tanks is pressurized with helium from a ground supply source. The helium control valve is activated 1.5 seconds after the Agena engine first start to permit helium gas to flow from the supply tank through fixed-area orifices to each propellant tank. After the Agena engine first cutoff, the helium control valve is again activated to isolate the oxidizer tank from the helium supply. This prevents the mixing of oxidizer and fuel vapors that could occur if pressures in the propellant tanks were permitted to reach the same level. Pressurization during the second powered phase of the Agena engine is provided by the residual pressure in the propellant tanks.

The propellant management system consists of the following major components: propellant fill couplings to permit the loading of fuel and oxidizer, feedlines from the propellant tanks to the engine pumps, tank sumps to retain a sufficient amount of propellants for engine start in a zero-gravity environment, a fuel dump valve and an oxidizer dump valve for discharging residual propellants through overboard vents, and an electric-motor-driven propellant isolation valve in each feedline. The propellant isolation valves are open at lift-off, closed after the Agena engine first cutoff, and opened 2 seconds before the Agena engine second start. When closed, these valves isolate the propellants in the tanks from the engine pump inlets and provide an overboard vent for propellants trapped in the engine pumps.

The Agena engine system consists of a liquid-bipropellant engine which uses unsymmetrical dimethylhydrazine as fuel and inhibited red fuming nitric acid as oxidizer. Rated thrust in a vacuum is 71 172 newtons (16 000 lbf) with a nozzle expansion area ratio of 45. The engine has a regeneratively cooled thrust chamber, a radiation-cooled nozzle extension, and a turbopump-fed propellant flow system. Turbine rotation is initiated for each engine start by igniting a solid-propellant start change. The turbine is driven during steady-state operation by hot gas produced in a gas generator. Propellants to the gas generator are supplied by the turbopump. An oxidizer fast-shutdown system consisting of a pyrotechnically operated valve and a high-pressure nitrogen storage cylinder is used to rapidly close the main oxidizer valve at engine first cutoff. (The oxidizer fast-shutdown system is not used at Agena engine second cutoff.) Engine thrust vector control is provided by the gimbal-mounted thrust chamber. Two hydraulic actuators provide the force for thrust chamber pitch and yaw movement in response to signals produced by the Agena guidance and flight control system.

The Thorad-Agena separation is accomplished by igniting a Mild Detonating Fuse which severs the booster adapter circumferentially near the forward end. The Thorad with booster adapter is then separated from the Agena by firing two solid-propellant retrorockets mounted on the booster adapter. Rated average sea-level thrust of each retrorocket is 2180 newtons (490 lbf) with an action time of 0.93 second. Guide rails on the booster adapter mate with rollers on the Agena aft rack to maintain clearance and alinement during separation.

Pyrotechnic devices are used to perform a number of functions on the Agena. These devices include squibs, igniters, detonators, and explosive-bolt cartridges. Squibs are used to release the horizon sensor fairings, to open and close the helium control valve, to actuate shroud boltcutters, and to activate the oxidizer fast shutdown system. Squibs are also used to open the oxidizer and fuel dump valves, to release the horizon sensor torque tube, and to operate one valve in the attitude control system and two valves in the attitude control gas dump system. (See the second part of the report for detailed discussion on opening the propellant dump values, horizon sensor torque tube rotation, and the attitude control gas dump system.) Igniters are used for the engine solid-propellant start charges and for the retrorockets. Detonators are used for the self-destruct charge and for the Mild Detonating Fuse separation charge. Cartridges are used to rupture the explosive bolts for release of the shroud bands.

System Performance

The Thorad-Agena separation system performance was normal. Separation was commanded by the radio guidance system at T + 239.96 seconds. The command resulted in the ignition of the Mild Detonating Fuse and the two retrorockets. The booster adapter guide rails cleared the rollers on the Agena aft rack at T + 242.53 seconds.

Agena engine first start was initiated by the Agena timer at T + 258.94 seconds. The engine switch group monitor data indicated a normal start sequence of the engine control valves. Ninety percent combustion chamber pressure was attained at T + 260.17 seconds. The average steady-state thrust produced by the Agena engine was 72 239 newtons (16 240 lbf), compared with an expected value of 72 528 newtons (16 305 lbf). Agena engine cutoff was commanded by the velocity meter at T + 492.29

seconds. The engine thrust duration, measured from 90 percent chamber pressure to velocity meter cutoff command, was 232.12 seconds. This was 0.57 second greater than the expected value of 231.55 seconds. The actual thrust duration and thrust level indicate that engine performance was within the allowable limits.

The propellant tank pressurization system performed satisfactorily during the Agena first powered phase. The fuel pump inlet pressure data were normal and remained within 1.4 N/cm^2 (2 psi) of the expected values. The oxidizer pump inlet pressure data were abnormal. A postflight evaluation indicated that an instrumentation problem caused the erroneous pressure data. (See Section 4 - COMMUNICATION AND CONTROL SYSTEM for discussion of this anomaly.)

The propellant isolation valves closed normally after Agena engine first cutoff and opened normally prior to engine second start, as evidenced by changes in pump inlet pressures.

Agena engine second start was initiated at T + 3357.98 seconds. The engine switch group monitor data indicated a normal start sequence of the engine control valves. Ninety percent combustion chamber pressure was attained at T + 3359.06 seconds. The average steady-state thrust produced by the Agena engine was 73 840 newtons (16 600 lbf), compared with an expected value of 72 826 newtons (16 372 lbf). Agena engine second cutoff was commanded by the velocity meter at T + 3363.70 seconds. The engine thrust duration, measured from 90 percent combustion chamber pressure to velocity meter cutoff command, was 4.64 seconds. This was 0.13 second less than the expected value of 4.77 seconds. The actual thrust duration and thrust level indicate that engine performance was within the allowable limits.

The propellant tank pressures during the Agena second powered phase were adequate for satisfactory engine operation. The fuel pump inlet pressure data were within 1.4 N/cm^2 (2 psi) of the expected values. The oxidizer pump inlet pressure data were also within 1.4 N/cm^2 (2 psi) of the expected values; however, these data are suspect because of the instrumentation anomaly noted during the Agena first powered phase.

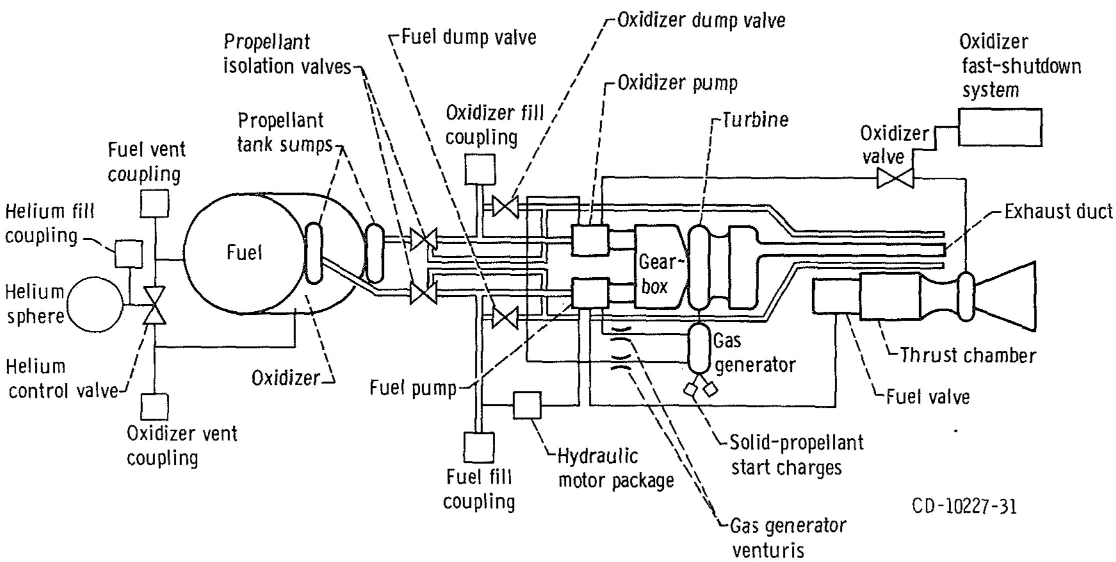


Figure 4-3. - Agena propulsion system, SERT II.

ELECTRICAL SYSTEM

by Baxter L. Beaton

System Description

The Agena electrical system (fig. 4-4) supplies all power requirements for the pyrotechnic, propulsion, flight termination, guidance and flight control, radio guidance, and telemetry systems. The electrical system consists of the power source equipment, the power conversion equipment, and the distribution network.

The power source equipment consists of four silver-zinc primary-type batteries and three nickel-cadmium secondary-type batteries. Three of the primary-type batteries (the main batteries) are connected in parallel and supply power to the Agena vehicle loads that use unregulated power, and to the power conversion equipment. These three primary-type batteries are each rated at 70 ampere-hours. The fourth primary-type battery (the pyrotechnic battery) is rated at 46 ampere-hours and supplies power to all Agena vehicle pyrotechnics except the destruct charges in the flight termination system. The pyrotechnic battery is also connected through a diode to the three main batteries so that it can support the loads on three main batteries. However, the diode isolates the loads on the three main batteries from pyrotechnic loads and pyrotechnic transients. Two of the secondary-type batteries are used with the flight termination system. The third secondary-type battery provides backup power for orbital operations (see Section 7: AGENA SYSTEMS DESCRIPTION - IN-ORBIT CONFIGURATION).

The power conversion equipment converts unregulated dc power to regulated ac and regulated dc power. The power conversion equipment consists of one solid-state inverter and two dc-dc converters. The inverter supplies 115 volts ac (±2 percent) at 400 hertz (±0.02 percent) to the guidance and flight control system. One dc-dc converter supplies regulated ±28.3 volts dc to the guidance and flight control system. The other dc-dc converter, which has two 28.3-volt dc regulated outputs, supplies the radio guidance system and the telemetry system.

System Performance

The Agena electrical system satisfactorily supplied power to all electrical loads throughout the flight, as indicated by comparison of measured with expected values. The electrical system performance data are summarized in table 4-1.

The battery (main and pyrotechnic) load profile was as expected for this mission. The inverter and converter voltages were within specifications throughout the flight.

The inverter frequency is not monitored on Agena vehicles; however, performance of the guidance and flight control system indicated the inverter frequency was normal and stable.

At approximately T + 389 seconds an Agena pyrotechnic circuit shorted to the vehicle structure. Approximately 0.6 second later the circuit was opened by a fuse resistor. There were no programmed events during this period. The short circuit did rot affect the performance of the Agena.

TABLE 4-1. - AGENA ELECTRICAL SYSTEM FLIGHT PERFORMANCE SUMMARY, SERT II

Measurement	Range	Measurement number	Flight values at-		
			Lift-off	Agena engine first start	Agena engine second start
Pyrotechnic battery voltage, V	22.5 to 29.5	C-141	28.4	27.1	26.0
Main battery voltage, V	22.5 to 29.5	C-1	28.2	27.4	25.9
Battery current, A	------------	C-4	12	15	12
Converter output:					
+28.3 V dc regulated (guidance and flight control)	27.7 to 28.9	C-3	28.4	28.3	28.3
-28.3 V dc regulated (guidance and flight control)	-27.7 to -28.9	C-5	-28.3	-28.3	-28.4
Inverter output, V ac rms:					
Phase AB	112.7 to 117.3	C-31	114.0	114.0	113.4
Phase BC	112.7 to 117.3	C-32	114.0	114.0	113.4
Converter output, + 28.3 V dc regulated:					
Telemetry	27.7 to 28.9	C-2	28.4	28.4	28.2
Radio guidance	27.7 to 28.9	BTL-6	28.1	28.1	28.4

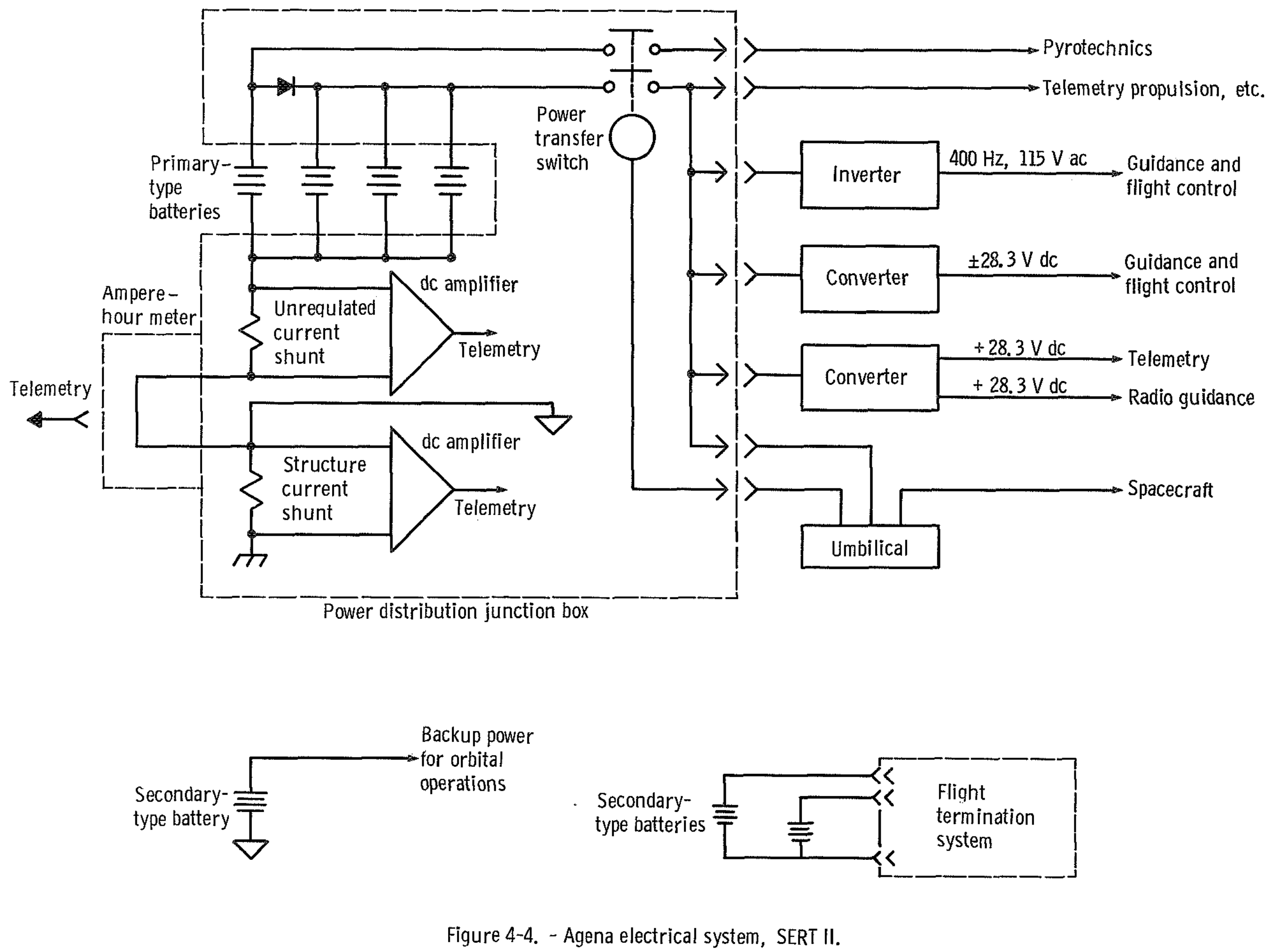


Figure 4-4. - Agena electrical system, SERT II.

GUIDANCE AND FLIGHT CONTROL SYSTEM

by Howard D. Jackson

The Agena flightpath is controlled by two interrelated systems: the Agena guidance and flight control system and the radio guidance system. The Agena guidance and flight control system directs the Agena, after Thorad-Agena separation, in a preprogrammed mode. The radio guidance system will supply, if needed, pitch and yaw steering commands during a major portion of the Agena first powered phase. These steering commands provide corrections for vehicle deviation from the desired trajectory. The radio guidance system also issues a discrete command to enable the Agena velocity meter about midway through the Agena first powered phase. The radio guidance system description, location of components, and use during the Thorad phase of flight, is provided in Section 3 - GUIDANCE AND FLIGHT CONTROL SYSTEM.

System Description

The Agena guidance and flight control system consists of three subsystems: a guidance subsystem, a flight control subsystem, and two timers to provide flight programming. A block diagram of the system is shown in figure 4-5.

The Agena guidance subsystem consists of an inertial reference package (IRP), horizon sensors, a velocity meter, and a guidance junction box. All components of the guidance subsystem are located in the guidance module in the Agena forward section. Primary attitude reference is provided by three orthogonal rate-integrating gyros in the IRP. These gyros are uncaged at Thorad vernier engine cutoff. The infrared horizon sensors (H/S), consisting of a left and right optical sensor (head) and a mixer box, provide pitch and roll error signals to the IRP. The horizon sensor pitch error signal is inhibited until after Agena engine first cutoff. For this mission the right H/S head is disabled during the period between Agena engine first and second cutoffs to eliminate the possibility of sun interference introducing attitude errors. The Agena yaw attitude is referenced to the attitude of the vehicle at the time of Thorad vernier engine cutoff. The velocity meter consists of an accelerometer, an electronics package, and a counter. The velocity meter accelerometer senses vehicle longitudinal acceleration. The velocity meter electronics processes the acceleration information and produces an output pulse each time the velocity increases by a known increment. The velocity meter counter generates an engine cutoff command when a predetermined number of pulses have been received (i.e., the sum of the velocity increments equals the total velocity to be gained). The guidance junction box serves as a center for guidance signals and contains relays for control of operating modes and gains.

The Agena flight control subsystem controls vehicle attitude and consists of a flight control electronics unit, a pneumatic and a hydraulic attitude control system (ACS), and a flight control junction box. Attitude error signals from the IRP are conditioned by the flight control electronics unit to operate the hydraulic and/or the pneumatic ACS.

During Agena coast periods, the pneumatic ACS provides pitch, yaw, and roll control. The pneumatic ACS, which uses a cold-gas mixture of nitrogen and tetrafluoromethane, consists of a gas sphere, a pressure regulator, and two thrust valve clusters with three thrust valves in each cluster. These components are located in the Agena aft section. A solenoid in the regulator provides for a high- or low-pressure mode of operation. In the high-pressure mode the regulated output pressure is about 68.9 N/cm^2 (100 psia) and each thrust valve produces 44.5 newtons (10 lbf) thrust. In the low-pressure mode the regulated output is 3.4 N/cm^2 (5 psia) and each thrust valve produces 2.22 newtons (0.5 lbf) thrust. The solenoid which determined high or low mode is controlled by timer preprogrammed commands. Each of the six thrust valves is operated by a solenoid and provides thrust as long as its solenoid is energized.

During Agena powered flight, the hydraulic ACS provides pitch and yaw control by means of two hydraulic actuators which gimbal the Agena engine thrust chamber, and the pneumatic ACS provides roll control.

A patch panel in the flight control junction box provides the means for preprogramming the interconnections of the guidance and flight control system to meet mission requirements.

Two Agena timers (primary and auxiliary) program the Agena flight events. Each is operated by a three-phase synchronous motor. Each can program 22 usable discrete events within a maximum running time of 6000 seconds. Each event controls a group of switches (two, three, or four switches per group) with separate normally open and normally closed contacts in each switch. Both timer motors are started before liftoff; however, brakes are engaged which prevent the timers from operating. The primary timer brake is released at Thorad main engine cutoff. The auxiliary timer brake is released by the primary timer at about T + 5701 seconds.

The radio guidance system steering control is transferred from the Thorad to the Agena within the airborne control package at Thorad-Agena separation. The capability of the Agena guidance and flight control system to accept radio guidance pitch and yaw steering commands is enabled 8 seconds before, and is disabled 142 seconds after, Agena engine first start, by the Agena primary timer. During this 150-second period of Agena flight, all radio guidance system pitch and yaw steering commands (generated by the ground-based computer and transmitted to the Agena) are routed to the Agena guidance and flight control system to provide corrections for deviations from the programmed trajectory.

The radio guidance system also provides the discrete command to the Agena for enabling the Agena velocity meter. The ground-based computer determines the time for this discrete command based on inflight performance of the Thorad and the Agena. With nominal Thorad and Agena performance, this discrete occurs about 133 seconds after Agena engine first start. After the radio guidance system has completed its planned period of operation, the airborne components are turned off to conserve Agena power. The Agena primary timer performs this function about 162 seconds after Agena engine first cutoff.

System Performance

The guidance and flight control system performance was satisfactory during the ascent phase of Agena operations. All events initiated by the Agena primary timer were within tolerance. A comparison of the expected and actual times of flight events is given in appendix A. The rates imparted to the Agena at Thorad-Agena separation (T + 239.96 sec) and the attitude errors at activation of the pneumatic ACS (T + 242.53 sec) were within the range of values experienced on previous flights, and are as follows:

(1) Rates imparted to Agena at separation, deg/sec:
- (a) Yaw, negligible
- (b) Roll, 0.83 clockwise
- (c) Pitch, 0.21 down

(2) Attitude errors at pneumatic ACS activation
- (a) Yaw, 0.17° right
- (b) Roll, 0.57° clockwise
- (c) Pitch, 3.40° down

(See fig. 4-6 for reference orientation.) The deadband limits of the pneumatic ACS were $\pm 0.2^{\circ}$ pitch, $\pm 0.18^{\circ}$ yaw and $\pm 0.6^{\circ}$ roll. The pitch attitude error was reduced to within the deadband limits in 11 seconds. The roll attitude error was also reduced to within the deadband limits in 11 seconds with an accompanying roll overshoot to 1.03° counterclockwise.

At T + 250.94 seconds the Agena initiated a programmed pitch down of 7.16° at a rate of 53.8 degrees per minute. The pitch-down rate was then decreased to 3.27 degrees per minute at Agena engine first start. For the Agena first powered phase the radio guidance system steering was enabled in pitch and yaw with the horizon sensors controlling only the roll gyro. At the time of Agena engine first start (T + 258. 94 sec), the roll attitude was offset at an error of 1.03° counterclockwise, and the vehicle was stable with the gyros at null in pitch and yaw.

Gas generator turbine spinup at Agena engine first start resulted in a roll rate and induced a maximum roll error as follows:

(1) Roll rate, 1.87 degrees per second clockwise

(2) Maximum roll error, 1.57° clockwise

(3) Time to reverse initial rate, 1.8 seconds

(See fig. 4-6 for reference orientation.)

Minimal attitude control was required during the Agena engine first powered phase and the vehicle attitude remained very close to null in pitch and yaw with a slight clockwise offset in roll due to turbine spin and exhaust duct misalinement. The attitude control activity (hydraulic and pneumatic) was normal throughout this phase. Radio guidance system steering commands were slight in both pitch and yaw during the period programmed for use.

The velocity meter, enabled by the radio guidance system at T + 392.56 seconds, commanded Agena engine first cutoff at T + 492.29 seconds when the vehicle had attained the required velocity increment. The roll transients caused by engine cutoff (i.e., turbine spindown and turbine exhaust decay) were similar to those experienced on previous flights. The time required to reduce the roll excursions to within the attitude control deadbands was 12.2 seconds.

Approximately 7 seconds after Agena engine first cutoff, a programmed geocentric rate of 3.75 degrees per minute (pitch down) was applied, and the pitch horizon sensor (H/S) was connected to the pitch gyro. The right H/S head was disabled by removing its power at T + 551.96 seconds. This prevented erroneous attitude signals (caused by sun interference with the right H/S head) during the long coast after first cutoff and during the second thrust period. The airborne components of the radio guidance system were turned off about 162 seconds after first cutoff. The left H/S, gyro, and thrust valve data showed that the vehicle maintained proper attitude during the coast period.

Minimal attitude control was required during the Agena engine second powered phase. Engine second-start (T + 3357.98 sec) and shutdown transients were similar to those experienced during first powered phase. Engine second cutoff was commanded by the velocity meter at T + 3363.70 seconds when the vehicle had attained the required velocity increment.

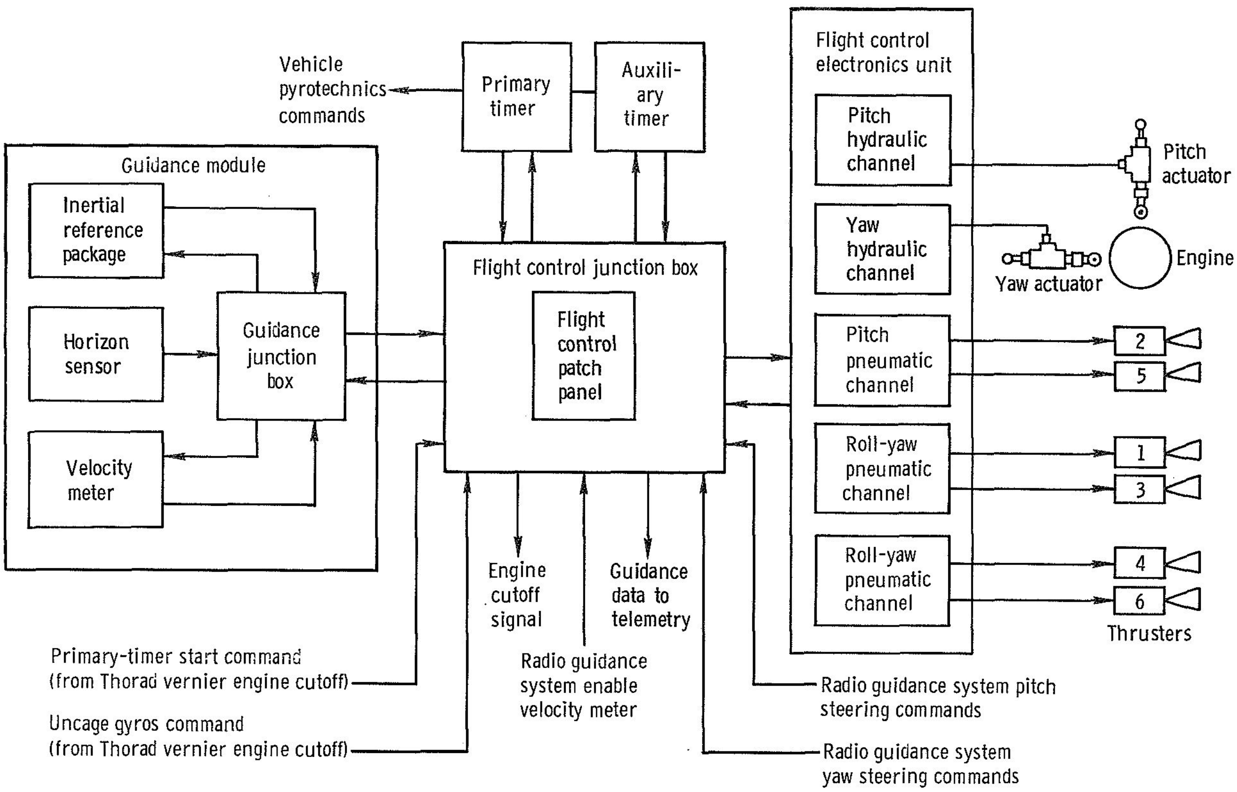


Figure 4-5. - Block diagram of Agena guidance and flight control system and radio guidance system functions, SERT II.

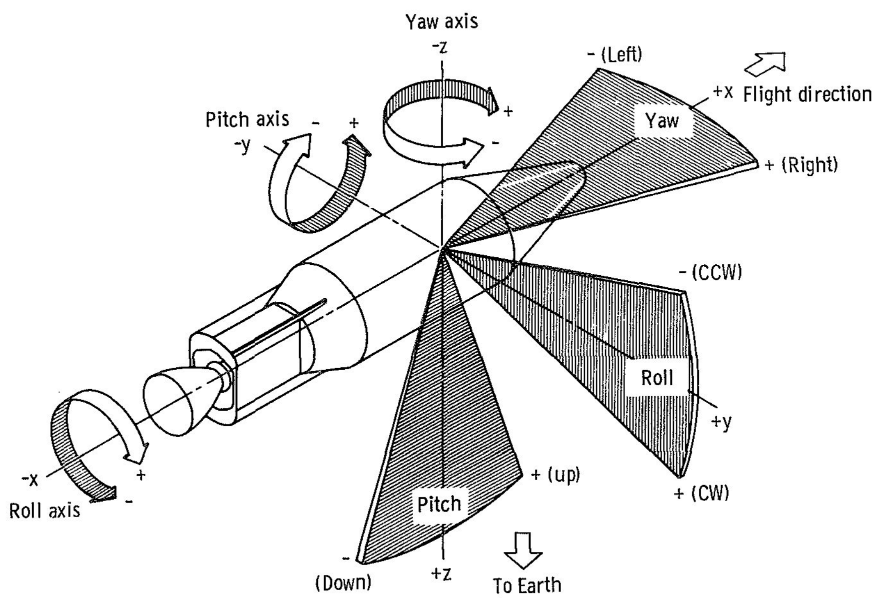


Figure 4-6. - Agena vehicle axes and vehicle movement designations, SERT II. Clockwise (CW) and counterclockwise (CCW) roll reference applies when looking forward along Agena longitudinal axis.

COMMUNICATION AND CONTROL SYSTEM

by Richard E. Orzechowski

System Description

The Agena communication and control system consists of telemetry, tracking, and flight termination subsystems with associated power supplies and cabling.

The telemetry subsystem is mounted in the Agena forward section. It monitors and transmits the Agena functional and environmental measurements during flight. The frequency modulation/frequency modulation (FM/FM) telemetry unit contains a very high frequency (VHF) transmitter, voltage-controlled oscillators, a commutator, a switch-and-calibrate unit, a radiofrequency (RF) switch, and an antenna. For the SERT II mission the telemetry antenna is located on the +Z-axis near Agena station 280. (See fig. 6-2 for orientation of the Z-axis for the ascent and orbit configuration.) Regulated 28-volt dc power for telemetry is supplied from a dc-dc converter. The RF switch connects the telemetry output to either the umbilical for ground checkout or the antenna for flight. The transmitter operates on an assigned frequency of 244.3 megahertz at a power output of 2 watts. The telemetry subsystem consists of 12 continuous subcarrier channels and two commutated subcarrier channels.

A total of 87 measurements are telemetered from the Agena vehicle. Appendix B summarizes the launch vehicle instrumentation. Three continuous subcarrier channels are used for monitoring acceleration and vibration data in the Agena forward section; three continuous channels are used for radio guidance system measurements; four continuous channels monitor the attitude control system thrust valve activity; one continuous channel is time shared by the velocity meter accelerometer and the velocity meter counter; and one continuous channel is used to monitor the 28-volt dc unregulated current. The turbine speed signal does not utilize a subcarrier channel but directly modulates the transmitter during engine operation. The remaining 73 measurements, and also the 28-volt dc unregulated current are monitored on the two commutated subcarrier channels. The channels are commutated at five revolutions per second with 60 segments on each channel.

The airborne tracking subsystem includes a C-band radar transponder, an RF switch, and an antenna. The transponder receives coded signals from the tracking radar on a carrier frequency of 5.630 gigahertz and transmits coded responses on a carrier frequency of 5.555 gigahertz at a minimum pulsed-power output of 200 watts at the input terminals of the antenna. The coded responses are at pulse rates (pulse repetition frequency) from 0 to 1600 pulses per second. The pulse rate is dependent upon the rates transmitted from the ground tracking stations and the number of stations simultaneously interrogating the transponder. The RF switch connects the output of the transponder to either the umbilical for ground checkout or the antenna for flight.

The Agena flight termination subsystem (located on the booster adapter) provides a range safety flight termination capability for the Agena from lift-off until Thorad-Agena separation. This subsystem is composed of two batteries, interconnecting wiring assemblies, two separation switches, a destruct initiator with two detonators, and a destruct charge. Flight termination can be initiated by a signal from either of the Thorad command receivers prior to Thorad-Agena separation, or automatically if Thorad-Agena separation occurs before Thorad main engine cutoff (i.e., prematurely). The automatic portion of the system is disabled at Thorad main engine cutoff to permit a normal Thorad-Agena separation.

A time-delay circuit in the Thorad safe-arm mechanisms ensures destruction of both stages by delaying Thorad destruct initiation until 0.1 second after Agena destruct initiation. Agena destruct is effected by ignition of a shaped charge mounted on the booster adapter, which ruptures the propellant tanks causing mixing of the hypergolic propellants.

System Performance

The telemetry subsystem performance was satisfactory throughout the flight. Signal strength data from all ground stations indicated an adequate and continuous signal level from the vehicle transmitter during the ascent phase. Analysis of the telemetry data indicated that the performance of the voltage-controlled oscillators, switch-and-calibrate unit, dc-dc converters and commutator was satisfactory.

Valid data were obtained from all Agena telemetered instrumentation except for measurement B2 (oxidizer pump inlet pressure), and measurement A519 (diaphram differential pressure). Data from measurement B2 (fig. 4-7) showed pressure values which did not follow the expected pressure-time history. Also step decreases in pressure occurred at T + 373, T + 435, and T + 468 seconds. A postflight evaluation of this anomaly concluded that the data from measurement B2 were suspect. Similar suspect data for this measurement have been observed on several previous USAF Agena missions. The transducer for measurement A519 failed to provide valid data. Instead of measuring the differential pressure across the shroud diaphram the measurement appeared to track ambient pressure during the ascent phase of flight. This indicates either a malfunction in the transducer or an obstruction in one of the sense lines to the transducer.

The tracking subsystem performance was satisfactory throughout the flight. The C-band transponder transmitted a continuous response to received interrogation during all periods of radar tracking.

Appendix C presents the coverage provided by the supporting telemetry and radar tracking stations for the ascent phase of the SERT II mission. Appendix E presents similar information for the in-orbit phase.

The Agena flight termination subsystem was not monitored during flight. However, because of system redundancy, it is assumed the system was capable of destructing the Agena throughout the Thorad powered phase.

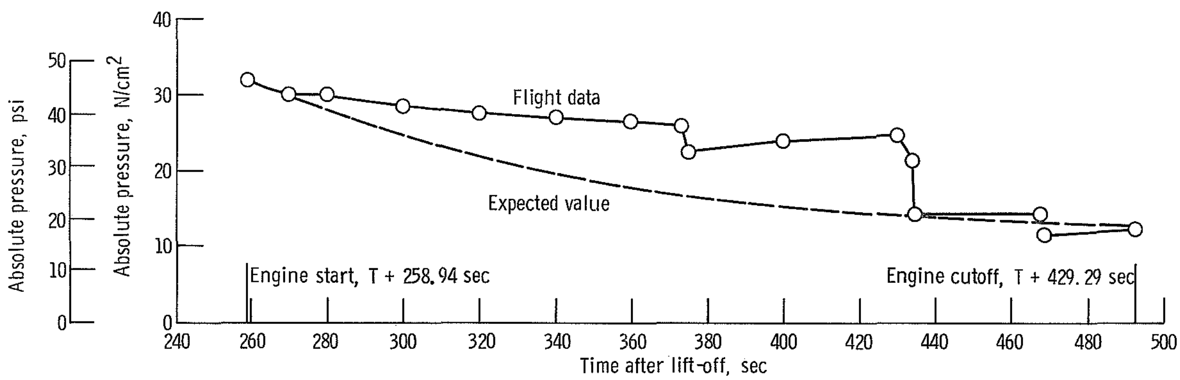


Figure 4-7. - Agena engine oxidizer pump inlet pressure (measurement B2, appendix B), SERT II.

5. LAUNCH OPERATIONS

by Howard A. Schwartzberg

The major prelaunch activities at the Western Test Range for the SERT II launch are shown in table 5-1. All prelaunch tests were completed satisfactorily. The significant problems which occurred during the prelaunch period are as follows:

(1) The Thorad fuel fill valve was replaced because a leakage was observed during a leak check.

(2) The pitch-roll actuator on Thorad vernier engine 1 was replaced because of a hydraulic oil leak.

(3) The Thorad inverter was replaced because the maximum continuous operating time of 15 minutes was exceeded. During the simulated countdown the inverter was not turned off as expected during power shutdown. As a result, the inverter operated for approximately 38 minutes. This problem was caused by a faulty fuse holder in the ground control equipment. This faulty fuse holder was repaired.

(4) The pitch-roll actuator on Thorad vernier engine 2 was replaced because of a hydraulic oil leak.

The countdown and scheduled launch for February 2, 1970, was aborted because of an anomaly in the Agena airborne radio guidance system. The radar transponder and command receiver in the Agena was replaced.

The countdown was again initiated on February 3 at 0855 Pacific standard time and the SERT II space vehicle was successfully launched at 1849:49.84 Pacific standard time on February 3, 1970. The performance of the launch vehicle ground equipment during the countdown and launch was satisfactory.

TABLE 5-1. - MAJOR PRELAUNCH ACTIVITIES AT

WESTERN TEST RANGE, SERT II

Date	Event
7/31/69	Thorad booster arrival at Vandenberg Air Force Base
8/20/69	Agena vehicle arrival at Vandenberg Air Force Base
12/09/69	Booster on stand
12/16/69	Agena on stand
1/13/70	Solar array installation
1/15/70	Agena mate to Thorad
1/15/70	Agena-Thorad erection
1/19/70	Spacecraft mate to Agena
1/26/70	Simulated countdown
2/03/70	Launch

AGENA IN-ORBIT PHASE

6. THE ORBITAL VEHICLE

by Rodney M. Knight and Eugene E. Coffey

VEHICLE DESCRIPTION

The orbital vehicle is designed to support the operation of the SERT II ion thrusters in a space environment. The orbital vehicle (fig. 6-1) consists of the SERT II spacecraft, a spacecraft support unit, and the Agena with attached solar arrays. The composite orbital vehicle is about 13 meters (42 ft) in width and 7.6 meters (25 ft) in length, weighing 1434 kilograms (3162 lbm).

Spacecraft

The SERT II spacecraft contains two experimental electron-bombardment mercury-ion thrusters, each designed for 6 months of continuous operation in space. The spacecraft is basically a cylinder 1.5 meter (5 ft) in diameter and 0.53 meter (1.75 ft) high, weighing 282 kilograms (621 lbm). Each ion thruster (design specific impulse, 4400 sec) generates a maximum thrust of 27.5×10^{-3} newtons (6.2×10^{-3} lbf). The performance of the experimental thrusters is determined by long-term (weeks or months) effects on orbit parameters. Each thruster weighs 23 kilograms (51 lbm), which includes 15 kilograms (34 lbm) of mercury. In addition to the two mercury-ion thruster experiments, the spacecraft contains five other experiments related to performance of the mercury-ion thrusters and also contains the power conditioning equipment for these thrusters.

Spacecraft Support Unit

The spacecraft support unit (SSU) contains two telemetry systems, two command systems, two tape recorders, and four control moment gyros. The SSU is basically a cylinder 1.5 meters (5 ft) in diameter and 0.53 meter (1.75 ft) high, weighing

220 kilograms (485 lbm). The SERT II spacecraft is attached to the forward end of the SSU, and the aft end of the SSU attaches to the Agena at the shroud transition ring. The command system has a capacity for 216 discrete commands. Three of these commands are hardwired to the Agena.

Agena Vehicle

The Agena stage, as an integrated part of the orbital vehicle, structurally supports the SSU and the two solar arrays. The Agena systems are described in Section 4: AGENA VEHICLE SYSTEM PERFORMANCE. For the SERT II mission the Agena was modified extensively. These modifications are described in detail in the following section. The weight of the Agena after discharge of residuals is 772 kilograms (1702 lbm).

Solar Arrays

Each solar array consists of hinged solar panels which fold into a compact package. Both arrays are attached to the aft rack of the Agena vehicle in a folded position. The Agena provides the command to initiate deployment of the arrays during the first orbit. When fully deployed, each array (fig. 6-2) is 5.7 meters (18.75 ft) long and 1.5 meters (5.0 ft) wide and is offset from the centerline of the Agena vehicle by about 0.2 meter (0.6 ft). Each array weighs about 80 kilograms (177 lbm). After deployment the two solar arrays convert solar energy to electrical energy for use by the spacecraft and the SSU.

ATTITUDE CONTROL

The orbital vehicle uses a combined gravity gradient (GG) and control moment gyro (CMG) system to maintain attitude in the required nose-down position with the solar arrays in the orbit plane. The GG-CMG system was selected for attitude control because it produces no thrust, and therefore the ion thruster performance can be measured directly without using correction factors.

The GG controls attitude about the orbital roll and orbital pitch axes. (See fig. 6-2 for axes conventions.) The CMG's control attitude about the orbital yaw axis, and also provide damping of orbital roll rates and orbital pitch rates. The maximum torque correction capability of the combined GG-CMG system is as follows

Axis	N-m	ft-lbf
Orbital pitch	$\pm 8.1\times10^{-3}$	$\pm 6\times10^{-3}$
Orbital yaw	$\pm 5.4\times10^{-3}$	$\pm 4\times10^{-3}$
Orbital roll	$\pm 4.9\times10^{-3}$	$\pm 3.6\times10^{-3}$

VEHICLE AXES CONVENTION

Figure 4-6 of this report defines the axes convention for the Agena vehicle in a nose-forward attitude. This convention applies from lift-off through the nose-down maneuver during the first orbit. Thereafter, a new axes convention, called the orbit convention, is defined for the orbital vehicle. Both conventions orient the pitch axis perpendicular to the orbit plane, the roll axis coincident with the velocity vector, and the yaw axis coincident with the local vertical. Figure 6-2 presents axes and movement designations for the ascent (nose forward) and orbit (nose down) conventions.

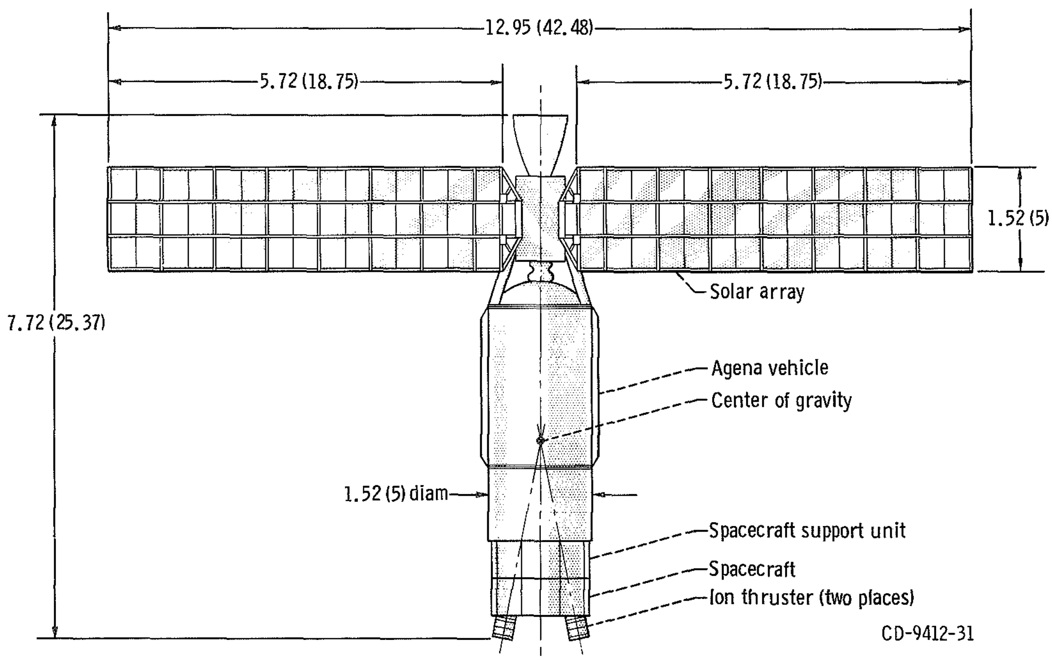
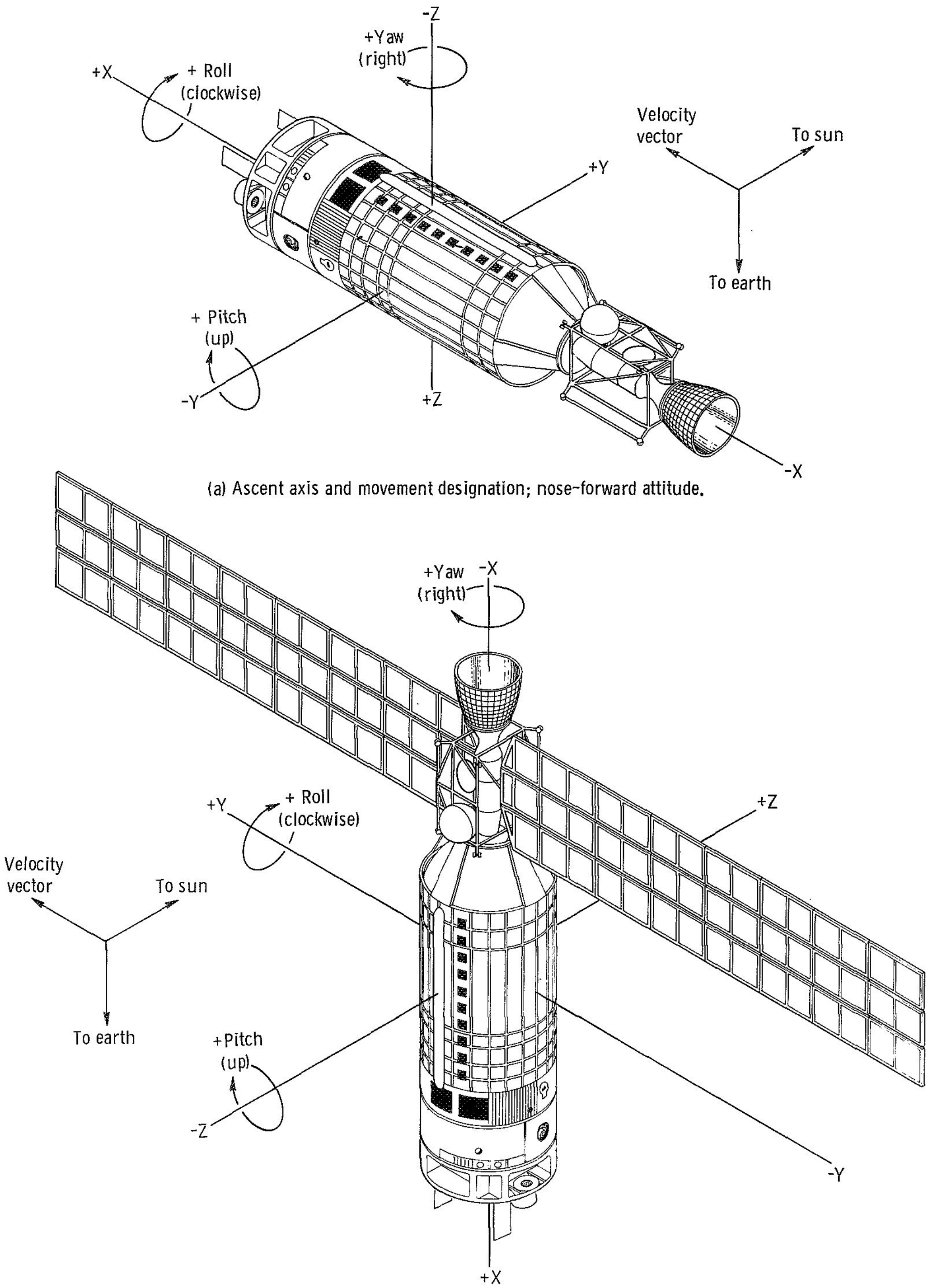


Figure 6-1. - Orbital vehicle configuration, SERT II. (Dimensions are in meters (ft).)



(a) Ascent axis and movement designation; nose-forward attitude.

(b) Orbit axis and movement designation; nose-down attitude.

Figure 6-2. - Ascent and orbital axis configuration, SERT II.

7. AGENA SYSTEMS DESCRIPTION (IN-ORBIT CONFIGURATION)

PROPELLANT DUMP SYSTEM

by Robert J. Schroeder

The Agena propellant dump system provides for the discharge of residual propellant (after Agena second cutoff) by preprogrammed commands. Two pyrotechnically operated dump valves (one for fuel and one for oxidizer) allow flow of residual propellant from the tanks and engine feedlines through the propellant isolation valve vent tubes (see fig. 4-3). The vent tubes are alined through the center of gravity of the orbital vehicle to minimize disturbance torques during discharge of propellant. The fuel dump valve is scheduled to open about 70 seconds after the oxidizer dump valve to prevent reversal of the structural bulkhead between the two propellant tanks.

Based on a nominal usage of propellants during the two thrust periods of the Agena engine, a total of 113.4 kilograms (250 lbm) of residual fuel, residual oxidizer, and helium pressurization gas is predicted to be discharged.

ATTITUDE CONTROL GAS DUMP SYSTEM

by Robert J. Schroeder

The Agena attitude control dump system provides for dumping (venting) of Agena residual attitude control system (ACS) gas by ground command. This system is composed of two pyrotechnically operated dump valves (start and abort), a dump pressure regulator, a fixed-area orifice, a pressure switch, and tubing. Figure 7-1 shows the hardware for this system and the ACS.

Dumping of the residual gas is initiated by opening the start dump valve. This allows high-pressure gas to flow from the storage sphere to the pressure regulator, where the outlet pressure is regulated within a range of 75.84 to 89.63 N/cm^2 (110 to 130 psi). The gas then flows through a fixed-area orifice, 0.140 centimeter (0.055 in.) in diameter, and out a dump tube which exits near the turbine exhaust duct outlet. The dump tube exit is alined through the center of gravity of the orbital vehicle to minimize disturbance torques. The regulator design provides for shutting off the flow of gas when the inlet pressure to the regulator reaches approximately 1.24 N/cm^2 (1.8 psi).

For the SERT II mission the residual ACS control gas, based on nominal usage during ascent and the first 14 orbits, is predicted to be 4.7 kilograms (10.4 lbm). This quantity of gas will be dumped within 1/4 to 1/2 orbit. The pressure switch provides a telemetry indication near the end of the dump when the outlet pressure of the pressure regulator reaches approximately 20.7 N/cm^2 (30 psi).

The magnitude of orbital vehicle torques resulting from dumping the residual gas may (under certain failure modes) exceed the ACS capability. Should this occur, the abort dump valve can be closed. Closing of this valve permanently stops the dump but does not affect the flow of gas to the ACS.

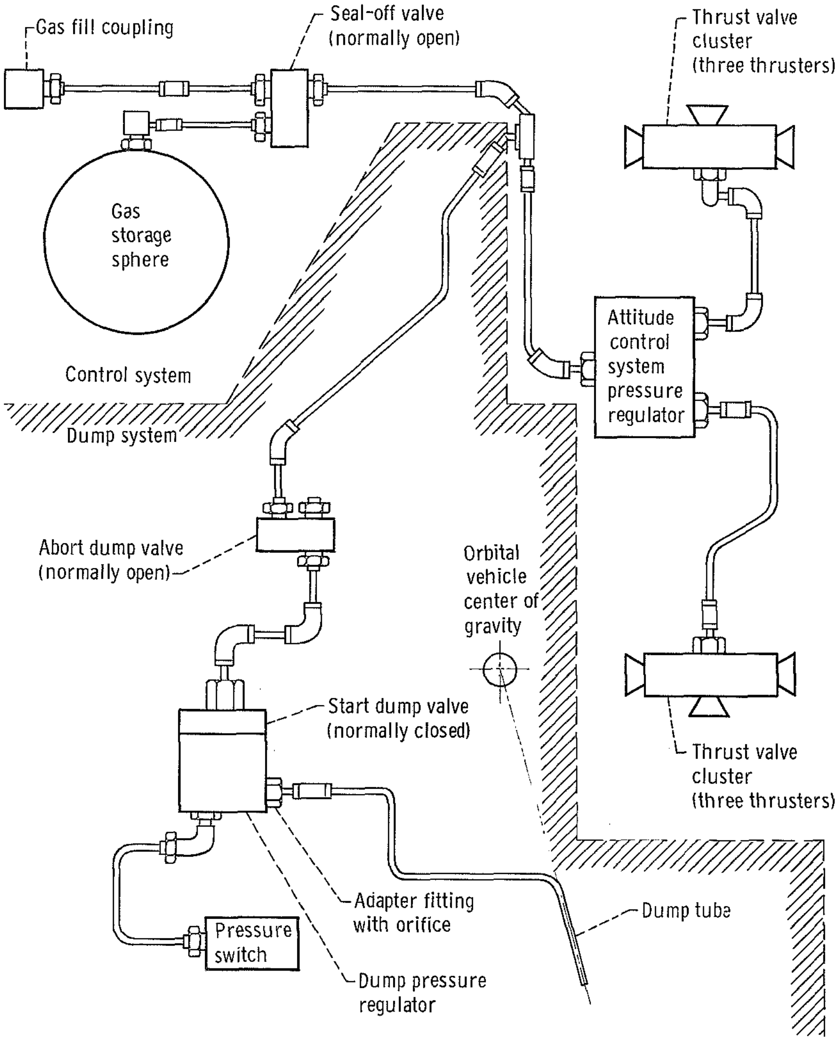


Figure 7-1. - Block diagram of Agena attitude control gas dump system and attitude control system, SERT II.

GUIDANCE AND FLIGHT CONTROL SYSTEM

by Howard D. Jackson

The basic equipment used in the guidance and flight control system, including the auxiliary timer, is described in Section 4 - GUIDANCE AND FLIGHT CONTROL SYSTEM and is shown in figure 4-5. The basic equipment is modified to meet the requirements of the orbital vehicle. These modifications include

(1) Addition of a pyrotechnically operated valve (see fig. 7-1) to seal off the attitude control system (ACS) gas remaining in the storage sphere

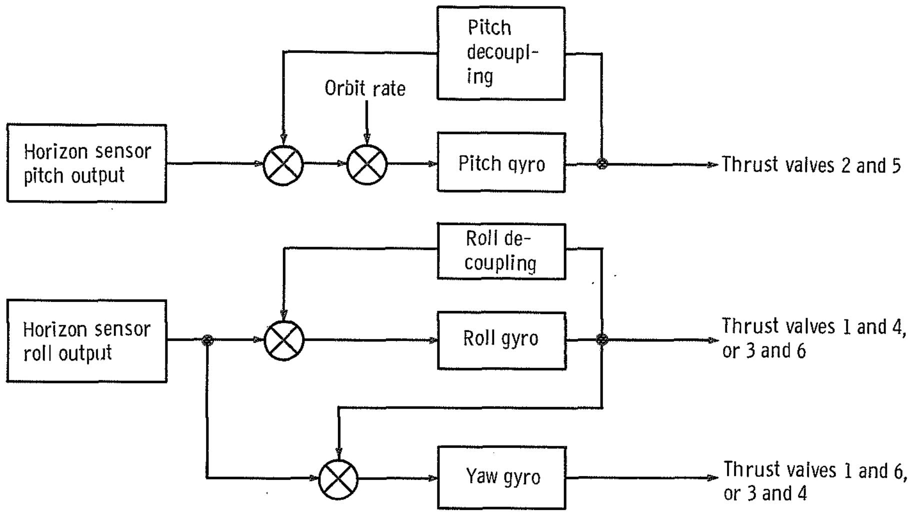
(2) Addition of circuits to provide individual monitoring of ACS thrust valves on three additional continuous-telemetry channels (two valves per channel)

(3) Circuit changes to permit ground command capability to activate and deactivate the ACS, permanently deactivate the ACS, and close the gas seal-off valve

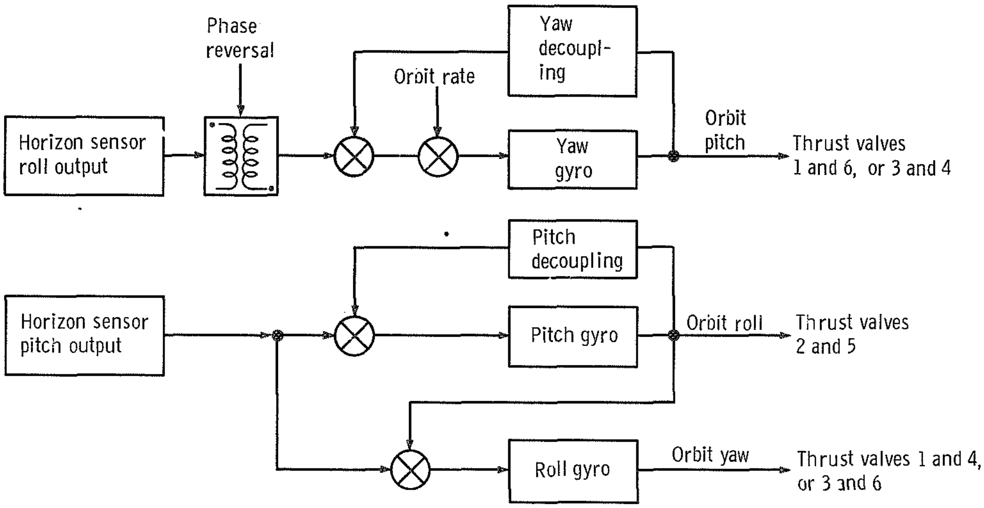
(4) Provisions for changing configuration of the guidance and flight control system to maintain the nose-forward attitude; to change to the nose-down attitude; and to maintain the nose-down attitude. Figure 7-2 shows the interconnection of the guidance and flight control equipment to maintain the nose-forward and the nose-down attitudes.

(5) Provisions for reorienting the horizon sensor (H/S) heads to view earth after the orbital vehicle has attained the nose-down attitude

(6) Shock mounting of the H/S torque tube to prevent pyrotechnic shock damage to the H/S system



(a) Nose-forward attitude with gyrocompassing (T + 3638 to T + 5701 sec).



(b) Nose-down attitude with gyrocompassing (after T + 6050 sec).

Figure 7-2. - Primary configurations of guidance and flight control system during orbital phase, SERT II.

ELECTRICAL SYSTEM

by Baxter L. Beaton

The basic equipment used in the Agena electrical system, including modifications to meet orbital power requirements, are described in Section 4: AGENA VEHICLE SYSTEM PERFORMANCE and are shown in figure 4-4. The modifications include the addition of two primary-type batteries, which extend the capability of Agena operations to a minimum of 37 hours after lift-off, a secondary-type battery to provide backup power to the Agena command and control junction box, and an ampere-hour meter system. The ampere-hour meter system consists of a current sensor and an ampere-hour meter. The ampere-hour meter converts a current flow signal, supplied by the sensor, to a digital form and stores the digital signal for discrete readout in 10 ampere-hour steps by Agena telemetry. Three commutated telemetry channels are used to provide a total readout capability of 630 ampere-hours.

Agena power consumption is reduced for the orbital operations by timer commands which remove power from the radio guidance system at T + 653 seconds, from the velocity meter system at T + 3638 seconds, from the primary timer at T + 5986 seconds, and from the auxiliary timer at T + 11 681 seconds. After removal of power from the above equipment, the Agena power consumption is predicted to be 170 watts.

AGENA COMMAND SYSTEM

by Edwin S. Jeris

The Agena command system provides ground command control capability of the Agena during in-orbit operations. A block diagram of the system is shown in figure 7-3. This system is designed to accept ground commands and to provide outputs to activate or deactivate the Agena attitude control system (ACS), start dump of residual ACS gas, abort dump of ACS gas (if necessary), connect the secondary-type battery to the system bus, seal off the gas storage sphere from the ACS thruster valves, permanently deactivate the ACS, and transfer the horizon-sensor (H/S) system power inputs from the Agena to the SERT II.

The Agena command system is enabled at T + 11 653 seconds by the auxiliary timer, which connects Agena unregulated 28-volt dc power to the main bus in the command-control junction box. This prepares the command system to accept any of three discrete ground commands. These ground commands are transmitted from the NASA Space Tracking and Data Acquisition Network (STADAN) ground station. (See appendix E for location of STADAN stations, location of ground stations to receive Agena telemetry data, and description of the use of these facilities during Agena orbital operations.) These three commands, which are received and decoded in the spacecraft support unit, are routed to the Agena command-control junction box. This box provides a variety of output functions depending upon the discrete command and the sequence of the commands. The Agena command system also contains instrumentation to provide Agena telemetry indications of command inputs and of output functions.

For a nominally performing orbital vehicle on the SERT II mission, a command sequence of four commands is planned for the Agena. This command sequence consists of command 1 (between orbits 7 and 12) to deactivate the Agena ACS; command 2 (orbit 14) to reactivate the Agena ACS; command 1 repeated (orbit 15) to start dump of Agena ACS gas; and command 3 (orbit 16 or 17) to seal off the ACS gas, deactivate the ACS, and transfer H/S control to the SERT II.

The command-control junction box also provides several different command options if the orbital vehicle does not perform as planned. One of these options provides for repeated activation or deactivation of the Agena ACS. One provides for aborting the ACS gas dump. One provides a backup to execute the functions of command 3, and one provides backup power (from the secondary-type battery) to the main bus in the junction box after T + 11 661 seconds.

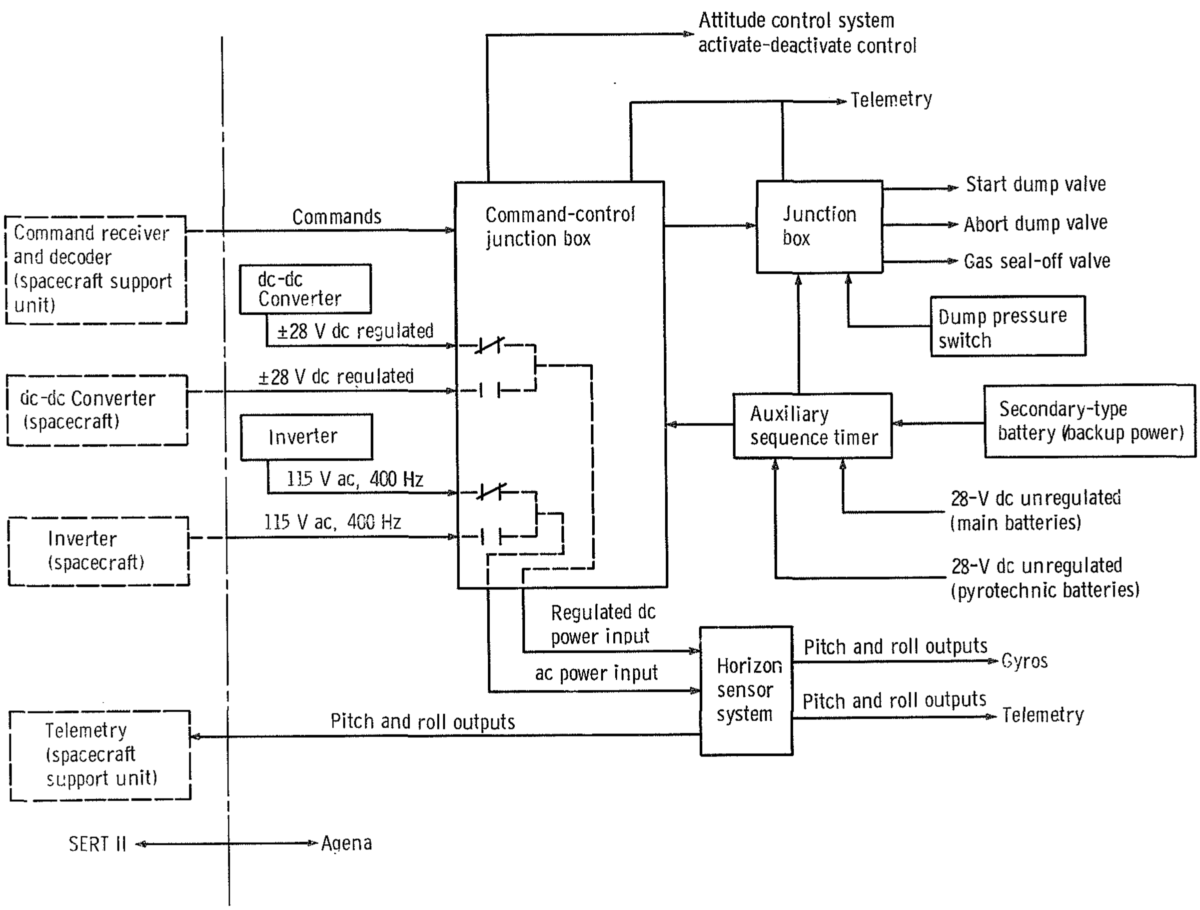


Figure 7-3. - Block diagram of Agena command system, SERT II.

8. AGENA IN-ORBIT OPERATIONS

by Roger S. Palmer

At the completion of the space vehicle ascent phase, the SERT II orbital vehicle is in an orbit plane nearly perpendicular to the sun-earth line. This orbit plane precesses at about 1^{o} per day, which keeps the orbital vehicle in sunlight for at least 6 months.

PLANNED PERFORMANCE

During the Agena in-orbit operations, the Agena (as part of the orbital vehicle) performs several active functions to place the orbital vehicle in a configuration which can support the SERT II ion thruster operation, and in the configuration for controlled measurement of ion thruster performance, for at least 6 months.

The in-orbit phase of Agena operations uses preprogrammed commands during the first two orbits and ground commands during subsequent orbits. The in-orbit phase begins at the end of the ascent phase (i.e., second cutoff of the Agena engine at T + 3363 sec) with the discharge of residual propellants. Each propellant discharges in a liquid form for a short period after its dump valve opens, and then as a gaseous mixture of propellant vapor and helium pressurization gas for several orbits. After the liquid phase of discharge is complete, the Agena primary timer provides commands that change configuration of the Agena to maintain a stable nose-forward attitude, and that start the auxiliary timer at T + 5701 seconds.

The auxiliary timer provides the remainder of the preprogrammed commands. These commands (see appendix A) orient the orbital vehicle to a nose-down attitude (by a 90^{o} yaw left followed by a 90^{o} pitch down), change the configuration of the Agena to maintain a stable nose-down attitude, initiate solar array deployment, enable the Agena to accept ground commands, and enable the secondary-type battery. The final event shuts the timer off at T + 11 681 seconds.

After the nose-down attitude is established and the solar arrays are fully deployed in the plane of the orbit, the orbital vehicle is in the required configuration for establishment of the gravity gradient - control moment gyro (GG-CMG) attitude control system (ACS), with the solar arrays facing the sun.

During the next several orbits, the Agena ACS provides attitude control while disturbance torques (primarily resulting from the gaseous phase of propellant discharge) decay. Also during this period the control moment gyros in the spacecraft support unit are turned on by ground command to the SERT II spacecraft, completing the capability of controlling the attitude of the orbital vehicle by the GG-CMG system. Agena horizon sensor (H/S) and gyro data are used to monitor the attitude of the orbital vehicle and Agena ACS thrust valve activity is monitored to provide for calculations of disturbance torques. When the calculated disturbance torques have decayed to within predetermined criteria (predicted to occur between orbits 7 and 12), the Agena ACS is deactivated by ground command. The orbital vehicle attitude is then controlled only by the GG-CMG system and the performance of the GG-CMG system is evaluated by monitoring Agena H/S data.

When the performance of the GG-CMG system has been determined to be satisfactory, the Agena ACS residual gas can be dumped. The Agena ACS is reactivated by ground command during orbit 14 to provide the capability for compensation of disturbance torques during the gas dump. Another ground command starts the gas dump on orbit 15. The Agena ACS thrust valve activity is monitored during the dump to determine if excessive disturbance torques exist which would require sending another ground command to abort the dump.

The final ground command to the Agena is sent on orbit 16 or 17. This command seals off gas remaining in the storage sphere from the Agena ACS thrust valves, provides permanent deactivation of the Agena ACS electronics, and transfers the Agena H/S system power inputs from the Agena to the SERT II.

This completes the Agena's active support to the mission. Thereafter the Agena acts as a pendulous mass for the GG-CMG system, and as structural support for other parts of the orbital vehicle.

ACTUAL PERFORMANCE

The preprogrammed commands and ground commands used during the in-orbit phase of Agena operations were properly initiated and executed. See appendix A for detailed sequence of events.

The in-orbit phase began at Agena engine second cutoff at T + 3363.70 seconds. At this time the oxidizer dump valve opened, and about 70 seconds later the fuel dump valve opened. The liquid phase of residual propellant discharge lasted about 110 seconds for the oxidizer, and about 50 seconds for the fuel. The Agena attitude control system (ACS) compensated for disturbance torques (primarily caused by the propellant discharge) and maintained the orbital vehicle in a stable nose-forward attitude.

At T + 5937.00 seconds, during orbit 1, the Agena began to orient the orbital vehicle to the nose-down attitude by yawing 90° left and then pitching 90° down. The nose-down attitude was satisfactorily established at T + 6032.03 seconds and, at the same time, the Agena horizon sensor (H/S) torque tube rotated the H/S heads to view earth. After the nose-down attitude was established, the Agena ACS remained active to counteract any disturbance torque that exceeded the capability of the GG-CMG system (see Section 6 for this capability). These torques could be caused by solar, magnetic, and aerodynamic effects, by misalinement of the principal axes, and by the discharge of residual propellant.

Solar array deployment was initiated, also during orbit 1, at T + 6352.10 seconds. The array on the +Y side of the Agena reached full deployment in about 32 seconds, and the array on the -Y side in about 37 seconds. The deployment was smooth and the resultant ACS thrust valve activity was negligible.

During orbit 5 the control moment gyros in the spacecraft support unit were turned on by ground command. Small disturbance torques occurred during the CMG spinup, but they decayed by the time the CMG's reached full speed. Calculations (using Agena ACS thrust valve activity data) of disturbance torques began during orbit 2. The disturbance torques decayed as expected and by orbit 6 were within permissible limits for deactivation of the Agena ACS. The maximum acceptable level for deactivation and the calculated values of disturbance torques during orbits 2 and 6 are shown in the following table:

Axis	Maximum acceptable level for deactivation		Orbit 2		Orbit 6	
	Disturbance torques					
	N-m	ft-lbf	N-m	ft-lbf	N-m	ft-lbf
Orbital pitch	$\pm 2.03 \times 10^{-3}$	$\pm 1.5 \times 10^{-3}$	38.1×10^{-3}	28×10^{-3}	$<1.36 \times 10^{-3}$	$<1.0 \times 10^{-3}$
Orbital yaw	$\pm 1.36 \times 10^{-3}$	$\pm 1.0 \times 10^{-3}$	1.09×10^{-3}	$.8 \times 10^{-3}$	$<1.36 \times 10^{-3}$	$<1.0 \times 10^{-3}$
Orbital roll	$\pm 1.36 \times 10^{-3}$	$\pm 1.0 \times 10^{-3}$	4.08×10^{-3}	3.0×10^{-3}	$<1.36 \times 10^{-3}$	$<1.0 \times 10^{-3}$

The planned sequence of four ground commands was sent to the Agena during subsequent orbits as shown in the following table:

Command number	Time sent		Command action
	Orbit	Hours from lift-off	
1	8	13:33:38	Deactivate Agena attitude control system (ACS)
2	13	22:42:43	Reactivate Agena ACS
1 (repeat)	15	26:05:01	Start ACS residual gas dump
3	17	29:32:29	Seal off ACS gas, permanently deactivate Agena ACS, transfer horizon sensor to SERT II

Agena telemetry data showed that each of these ground commands was properly received and executed.

After the first ground command deactivated the Agena ACS, the orbital vehicle attitude was satisfactorily controlled by the gravity gradient - control moment gyro system, as indicated by Agena H/S data. The second ground command satisfactorily reactivated the Agena ACS in preparation for the ACS gas dump.

The third ground command (command 1 repeated) started the dump of ACS residual gas. At the start of dump about 9.03 kilograms (19.9 lbm) of gas remained. The gas dump was continuously monitored by Agena telemetry for 25 minutes. Agena ACS thrust valve activity started about 5 seconds after the start of dump. About 6 minutes later the orbital vehicle had attained a steady-state attitude as indicated by constant pulsing of the thrust valves through the remainder of the 25-minute telemetry coverage. The disturbance torques, calculated for the period when the constant pulsing of the thrust valves occurred, were as follows:

Axis	Dump disturbance torque	
	N-m	ft-lbf
Orbital pitch	34.7×10^{-2}	25.5×10^{-2}
Orbital yaw	1.44×10^{-2}	1.06×10^{-2}
Orbital roll	1.51×10^{-2}	1.11×10^{-2}

These torques were within the capability of the Agena ACS, and the orbital vehicle was satisfactorily maintained within the ACS deadband limits of $\pm 3^{\circ}$ in all three axes.

The next acquisition of telemetry data occurred at the Canary Island station about 75 minutes after the start of dump. At this time the disturbance torques were essentially zero and the orbital vehicle attitude was satisfactorily controlled by the GG-CMG system.

The average mass flow rate of gas through the dump system during the 25-minute period was 3.8×10^{-3} kilogram per second (8.5×10^{-3} lbm/sec), nearly identical to the predicted value. At the Canary Island station acquisition of telemetry data, the pressure switch measurement on the dump system indicated that the gas storage sphere pressure was less than 20.7 N/cm^2 (30 psia).

After the fourth ground command (command 3), Agena telemetry data showed that the H/S system was performing satisfactorily with power supplied from SERT II. The Agena battery power was depleted at about T + 54 hours between orbits 31 and 32.

Appendix E presents the tracking and data acquisition coverage for the in-orbit phase. Appendix F presents temperature data for of the nine temperature measurements on the Agena.

CONCLUDING REMARKS

The Thorad-Agena launch vehicle, carrying the SERT II orbital vehicle, was successfully launch from Vandenberg Air Force Base, California, at 1849:49.84 hours Pacific standard time February 3, 1970. The 1545-kilogram orbital vehicle (consisting of the SERT II spacecraft, a spacecraft support unit, the Agena, and two solar arrays attached to the Agena) was placed into the desired orbit. This near-polar, near-circular orbit had an altitude of about 1010 kilometers, with the orbit plane established approximately perpendicular to the sun-earth line and maintained so by precessing at about 1° per day (i.e., sun synchronous).

During the first 17 orbits of the orbital vehicle, Agena operations to prepare for the SERT II experiment (electron-bombardment mercury-ion thruster performance) were successfully accomplished. These Agena operations included establishing the orbital vehicle in the nose-down attitude, deploying the solar arrays, discharging Agena residual propellants, venting Agena residual control gas, and transferring the operation of the Agena horizon sensors to the SERT II spacecraft. After the 17th orbit the Agena provided only passive support to the gravity gradient - control moment gyro (GG-CMG) stabilization system. A total of 111 kilograms of residuals (propellants and gas) was discharged overboard during these Agena operations.

The Agena horizon sensors were most recently commanded on (for the 45th time) by SERT II on February 11, 1971. Their performance remained satisfactory.

The SERT II spacecraft provided valuable data on the operation of the mercury-ion thruster system in a space environment. The first thruster operated continuously for a $5\frac{1}{4}$-month period. The second thruster was then turned on and operated continuously for $2\frac{3}{4}$ months. This was the first NASA usage of the Agena as part of an orbital vehicle for an unmanned program.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, February 23, 1971,
493-01.

APPENDIX A

SEQUENCE OF EVENTS, SERT II

by Richard L. Greene

THORAD-AGENA ASCENT PHASE

Nominal time, sec	Actual time, sec	Event description	Initiated by-
0	0	Lift-off	------------
38.61	38.3	Solid-propellant rocket motor burnout (average time of three motors)	------------
102.0	102.8	Solid-propellant rocket-motor-case jettison	Thorad timer
222.70	223.92	Thorad main engine cutoff	Radio guidance system
222.70	223.92	Start Agena primary timer and disarm Agena premature separation destruct	Thorad main engine cutoff
231.70	232.99	Thorad vernier engine cutoff, Agena gyro uncaging, and Agena horizon sensor (H/S) fairing jettison	Thorad time-delay relay
238.31	239.96	Thorad-Agena separtion	Radio guidance system
239.01	240.31	Transfer radio guidance system steering to Agena, and correct H/S roll output to roll gyro	Pull-away plug
240.87	242.53	Activate pneumatic attitude control system (ACS)	Separation switch
249.70	250.94	Start 53.8-deg/min pitchdown rate, connect velocity meter accelerometer output to telemetry, and enable radio guidance system pitch and yaw steering	Agena primary timer
257.70	258.94	Transfer to 3.27-deg/min pitch-down rate and deactivate pitch-and-yaw pneumatics; Agena engine first start	Agena primary timer
258.85	260.17	Agena engine at 90 percent chamber pressure	------------------
259.20	260.49	Open helium control valve	Agena primary timer
267.70	268.95	Shroud jettison	Agena primary timer
390.84	392.56	Enable velocity meter	Radio guidance system
399.70	(a)	Disable radio guidance system pitch and yaw steering	Agena primary timer
490.40	492.29	Agena engine first cutoff, reactivate pitch and yaw pneumatics, and oxidizer fast shutdown	Velocity meter
497.70	498.95	Close propellant isolation valves, transfer to 3.75-deg/min pitch-down rate, connect H/S pitch output to pitch gyro, and telemetry calibrate	Agena primary timer
550.70	551.96	Remove power from right H/S head, transfer ACS to low-pressure mode, disconnect H/S roll output from roll gyro, change H/S pitch and flight control gains, change gyro telemetry signals to low range, and change ACS dead bands	Agena primary timer
648.70	(b)	Close helium control valve	Agena primary timer

[a]No telemetry measurement to determine event time.
[b]No telemetry coverage to determine event time.

Nominal time, sec	Actual time, sec	Event description	Initiated by-
652.70	(b)	Remove power from radio guidance system and disable velocity meter	Agena primary timer
3341.70	3342.97	Transfer ACS to high-pressure mode, change H/S pitch and flight control gains, change gyro telemetry signals to high range, change ACS deadbands, transfer velocity meter counter output to telemetry, and load velocity meter counter with velocity to be gained for second powered phase	
3354.70	3355.98	Open propellant isolation valves, transfer velocity meter acceleromater output to telemetry, and enable velocity meter	
3356.70	3357.98	Agena engine second start; deactivate pitch and yaw pneumatics	
3357.83	3359.06	Agena engine at 90 percent chamber pressure	-------------------
3362.60	3363.70	Agena engine second cutoff; reactivate pitch and yaw pneumatics	Velocity meter
3362.60	3363.70	Open oxidizer dump valve	Agena engine second cutoff
3363.70	(a)	Transfer to 3.43-deg/min pitch-down rate (geocentric)	Agena primary timer
3378.70	3379.99	Telemetry calibrate, transfer velocity meter counter output to telemetry, disable velocity meter, and connect power to right H/S head	
3381.70	3382.97	Transfer velocity meter accelerometer output to telemetry and connect H/S roll output to roll gyro	
3432.70	3433.98	Open fuel dump valve	
3637.70	3638.98	Transfer ACS to low-pressure mode, connect gyro decoupling circuits, change H/S and flight control gains, change gyro telemetry signals to low range, change ACS deadbands, connect H/S roll and roll gyro outputs to yaw gyro (nose-forward gyrocompassing), and remove power from velocity meter	
5700.70	5702.09	Transfer ACS to high-pressure mode, disconnect gyro decoupling circuits, change H/S and flight control gains, change gyro telemetry signals to high range, change ACS deadbands, stop nose-forward gyrocompassing, and start auxiliary timer	
5935.70	5937.00	Stop 3.4-deg/min pitch-down rate (geocentric), start 180-deg/min yaw-left rate	Agena auxiliary timer
5965.70	5967.00	Stop 180-deg/min yaw-left rate	
5985.70	5987.04	Start 120-deg/min pitch-down rate, start 3.43-deg/min orbit pitch-down rate (geocentric), rotate H/S torque tube.	
6030.70	6032.03	Stop 120-deg/min pitch-down rate, start 3.43-deg/min orbit pitch-down rate (geocentric), rotate H/S torque tube	
6050.70	6052.03	Connect H/S pitch output to pitch gyro, connect H/S roll output with phase reversal to yaw gyro, connect H/S pitch and pitch gyro outputs to roll gyro (nose-down gyrocompassing), connect gyro decoupling circuits, change H/S and flight control gains, and change gyro telemetry signals to low range	

[a]No telemetry measurement to determine event time.
[b]No telemetry coverage to determine event time.

Nominal time, sec	Actual time, sec	Event description	Initiated by-
6340.70	(a)	Transfer ACS to low-pressure mode	Agena auxiliary timer
6350.70	6352.10	Initiate solar array deployment	Agena auxiliary timer
---------	6384.2	+Y-axis solar array fully deployed	-------------------
---------	6389.3	-Y-axis solar array fully deployed	-------------------
6471.70	(a)	Enable spacecraft battery	Agena auxiliary timer
6652.70	(a)	Change ACS deadbands	
11 652.70	11 654.16	Enable Agena command system	
11 660.70	11 662.25	Enable secondary-type battery, enable ACS gas abort dump valve and seal off valve	
11 670.70	11 672.25	Enable ACS gas start dump valve	
11 680.70	11 682.13	Remove power from auxiliary timer	

[a]No telemetry measurement to determine event time.

AGENA ORBIT PHASE - GROUND COMMANDS

Command sent		Command action	Ground command number
Hours from lift-off	Orbit number		
13:33:38	8	Deactivate ACS	1
22:42:43	13	Activate ACS	2
26:05:01	15	Start ACS residual gas dump	1 (repeat)
29:32:29	17	Seal off ACS gas, permanently deactivate ACS electronics, transfer H/S power inputs to SERT II	3

APPENDIX B

LAUNCH VEHICLE INSTRUMENTATION SUMMARY, SERT II

by Richard L. Greene and Richard E. Orzechowski

THORAD TELEMETRY

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
FM-1-01	Inverter frequency	1	370.0 to 430.0 Hz	
FM-1-07	Sequence 3: Solid motor 1 jettison Solid motor 2 jettison Solid motor 3 jettison	7	0 to 5 V	
FM-1-08	Sequence 1: Programmer start Liquid-oxygen tank float switch Fuel tank float switch Main engine cutoff Vernier engine cutoff	8	0 to 5 V	
FM-1-09	Vernier engine 2 chamber pressure, absolute	9	0 to 344.5 N/cm^2	0 to 500 psi
FM-1-10	Sequence 2: Solid motor ignition arm Solid motor ignition Solid motor jettison arm Solid motor jettison command	10	0 to 5 V	
FM-1-11	Main engine chamber pressure, absolute	11	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-12	Turbopump speed	12	0 to 8000 rpm	
FM-1-13	Solid motor 1 chamber pressure, absolute	13	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-A	Solid motor 3 chamber pressure, absolute	A	0 to 551.5 N/cm^2	0 to 800 psi
FM-1-C	Solid motor 2 chamber pressure, absolute	C	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-01	5-Volt transducer calibration voltage	E, seg. 1	0 to 5 V	
PDM-1-02	Instrumentation ground	E, seg. 2	0 to 5 V	
PDM-1-03	Main engine pitch position	E, seg. 3	-5° to 5°	
PDM-1-04	Main engine yaw position	E, seg. 4	-5° to 5°	
PDM-1-05	Vernier engine 1 pitch-roll position	E, seg. 5	-45° to 45°	
PDM-1-06	Vernier engine 1 yaw position	E, seg. 6	-28° to -8°	
PDM-1-07	Vernier engine 2 pitch-roll position	E, seg. 7	-45° to 45°	
PDM-1-08	Vernier engine 2 yaw position	E, seg. 8	8.0° to 28.0°	
PDM-1-09	Pitch attitude error	E, seg. 9	-5° to 5°	

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
PDM-1-10	Yaw attitude error	E, seg. 10	-5° to 5°	
PDM-1-11	Roll attitude error	E, seg. 11	-7° to 7°	
PDM-1-12	Pitch rate	E, seg. 12	-5 to 5 deg/sec	
PDM-1-13	Yaw rate	E, seg. 13	-5 to 5 deg/sec	
PDM-1-14	Roll rate	E, seg. 14	-8 to 8 deg/sec	
PDM-1-15	Pitch command	E, seg. 15	-4 to 4 deg/sec	
PDM-1-16	Yaw command	E, seg. 16	-4 to 4 deg/sec	
PDM-1-17	Actuator potentiometer positive voltage	E, seg. 17	0 to 30 V	
PDM-1-18	Actuator potentiometer negative voltage	E, seg. 18	-30 to -13 V	
PDM-1-19	400-Hertz phase A inverter voltage	E, seg. 19	109 to 121 V	
PDM-1-20	5-Volt potentiometer excitation voltage	E, seg. 20	0 to 5 V	
PDM-1-21	Control electronic amplifier, +165 V dc	E, seg. 21	0 to 200 V	
PDM-1-22	Main engine chamber pressure, absolute	E, seg. 22	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-23	Main battery voltage	E, seg. 23	0 to 32 V	
PDM-1-24	Telemetry battery voltage	E, seg. 24	0 to 32 V	
PDM-1-25	Hydraulic supply pressure, absolute	E, seg. 25	0 to 2756 N/cm^2	0 to 4000 psi
PDM-1-26	Hydraulic return pressure, absolute	E, seg. 26	0 to 137.8 N/cm^2	0 to 200 psi
PDM-1-27	Roll command	E, seg. 27	-8 to 8 deg/sec	
PDM-1-28	Turbine inlet temperature	E, seg. 28	255 to 1255.4 K	-200° to 1800° F
PDM-1-29	Fuel pump inlet pressure, absolute	E, seg. 29	0 to 137.8 N/cm^2	0 to 200 psi
PDM-1-30	Flight termination receiver 1 automatic gain control voltage	E, seg. 30	0.00 to 5000 μV	
PDM-1-31	Vernier engine 1 housing temperature (left)	E, seg. 31	255 to 810.9 K	0° to 1000° F
PDM-1-32	Vernier engine 2 housing temperature (right)	E, seg. 32	255 to 810.9 K	0° to 1000° F
PDM-1-33	Engine pneumatic bottle pressure, absolute	E, seg. 33	0 to 3447 N/cm^2	0 to 5000 psi
PDM-1-34	Control electronics amplifier -165 V dc	E, seg. 34	-200 to 0 V	

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
PDM-1-35	Main engine pitch actuator temperature	E, seg. 35	255 to 810.9 K	0^{o} to 1000^{o} F
PDM-1-36	Flight termination receiver 2 automatic gain control voltage	E, seg. 36	0 to 5000 μV	
PDM-1-37	Air conditioning duct inlet temperature	E, seg. 37	255 to 810.9 K	0^{o} to 1000^{o} F
PDM-1-38	Skirt section temperature	E, seg. 38	255 to 810.9 K	0^{o} to 1000^{o} F
PDM-1-39	Liquid-oxygen pump inlet pressure, absolute	E, seg. 39	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-40	Main fuel tank top pressure, absolute	E, seg. 40	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-41	Gas generator liquid-oxygen injector pressure, absolute	E, seg. 41	0 to 551.5 N/cm^2	0 to 800 psi
PDM-1-42	Liquid-oxygen tank top pressure, absolute	E, seg. 42	0 to 68.9 N/cm^2	0 to 100 psi
PDM-1-43	Liquid-oxygen pump inlet	E, seg. 43	88 to 102.6 K	-300.0^{o} to -275.0^{o} F

AGENA TELEMETRY

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
AD032	Shroud separation monitor	15-44	(b)	
A632	+Y Solar array extension switch	16-25/55	(b)	
A633	-Y Solar array extension switch	16-26/56	(b)	
A519	Diaphragm differential pressure	16-23/53	-3.4 to 3.4 N/cm^2	-5 to 5 psi
B1	Fuel pump inlet pressure, gage	15-15	0 to 68.9 N/cm^2	0 to 100 psi
B2	Oxidizer pump inlet pressure, gage	15-17	0 to 68.9 N/cm^2	0 to 100 psi
B11	Oxidizer venturi inlet pressure, absolute	15-19/49	0 to 1034 N/cm^2	0 to 1500 psi
B12	Fuel venturi inlet pressure, absolute	15-23/53	0 to 1034 N/cm^2	0 to 1500 psi
B13	Switch group Z (propulsion system monitor)	15-7/22/37/52	(b)	
B32	Oxidizer pump inlet temperature	15-8	255 to 311 K	0^{o} to 100^{o} F
B31	Fuel pump inlet temperature	15-6	255 to 311 K	0^{o} to 100^{o} F
B35	Turbine speed	(c)		
B91	Combustion chamber pressure, gage	15-4/34	328 to 379 N/cm^2	475 to 550 psi

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

[b]Events are indicated by a step change in telemetry voltage.

[c]The turbine speed signal does not utilize a subcarrier channel, but directly modulates the transmitter during engine operation.

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
C1	28-Volt dc unregulated supply	16-40	22 to 30 V dc	
C2	28-Volt dc regulator 3	16-33	22 to 30 V dc	
C3	28-Volt dc regulator 1 (guidance and control)	15-12	22 to 30 V dc	
C4	28-Volt dc unregulated current	16-13/44; and 17	0 to 100 A	
C5	-28-Volt dc regulator 1 (guidance and control)	15-30	-30 to -22 V dc	
C21	400-Hertz, three-phase-inverter temperature	15-14	255 to 367 K	0° to 200° F
C31	400-Hertz, three-phase bus, phase AB	15-18	90 to 130 V ac	
C32	400-Hertz, three-phase bus, phase BC	15-20	90 to 130 V ac	
C38	Structure current monitor	15-10/25/40/55	0 to 50 A	
C81	Command 2 monitor	16-22	(d)	
C82	Command 3 monitor	16-24	(d)	
C83	28-Volt dc regulated supply	15-31	22 to 30 V dc	
C84	-28-Volt dc regulated supply	16-31	-30 to -22 V dc	
C86	Command 1 monitor	16-34	(d)	
C87	Arm command 1-2 monitor	15-51	(b)	
C88	Command power bus monitor	16-2		
C89	Backup power bus monitor	16-8		
C90	Enable command 2 and 3 monitor 1	15-11		
C91	Enable command 2 and 3 monitor 2	16-12		
C92	Pneumatics on-off monitor	16-18		
C93	Pneumatics pyrotechnic shutdown monitor 1	16-20		
C94	Pneumatics pyrotechnic shutdown monitor 2	16-21		
C95	Enable command 1-3 monitor	16-6		
C96	Arm command 2-X abort monitor	16-10		
C97	Dump disable monitor	16-14		
C98	Dump pressure switch monitor	15-33		
C99	Pressure switch arm abort monitor	15-45		
C100	Pressure switch abort monitor	15-26		
C101	Abort pyrotechnic monitor 1	15-48		
C102	Abort pyrotechnic monitor 2	16-16		
C103	Isolation pyrotechnic monitor 1	15-13		
C104	Isolation pyrotechnic monitor 2	15-56		

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

[b]Events are indicated by a step change in telemetry voltage.

[d]Events are indicated by a transient pulse in telemetry voltage.

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
C105	Dump pyrotechnic monitor 1	15-16	(d)	
C106	Dump pyrotechnic monitor 2	15-38	(d)	
C130	Ampere-hour meter 1	16-50	0 to 30 A-hr	
C131	Ampere-hour meter 2	16-51	40 to 20 A-hr	
C132	Ampere-hour meter 3	16-52	160 to 480 A-hr	
C141	Pyrotechnic bus voltage	15-5/35	20 to 30 V dc	
D7	X-axis acceleration	11	-4 to 12 g	
D8	Y-axis acceleration	8	-1.5 to 1.5 g	
D9	Z-axis acceleration	9	-1.5 to 1.5 g	
D14	Guidance and control event monitor	16-27	(b)	
D41	Horizon sensor pitch	16-45	-5° to 5°	
D42	Horizon sensor roll	16-46	-5° to 5°	
D46	Thrust valve cluster temperature, +Z axis	15-39	228 to 339 K	-50° to 150° F
D47	Thrust valve cluster temperature, -Z axis	15-36	228 to 339 K	-50° to 150° F
D51	Yaw torque rate	16-38	-10 to 10 deg/min (orbit mode) -200 to 200 deg/min (ascent mode)	
D54	Horizon sensor head temperature, (right)	15-47	228 to 367 K	-50° to 200° F
D55	Horizon sensor head temperature, (left)	15-46	228 to 367 K	-50° to 200° F
D59	Control gas supply pressure, absolute	16-47	0 to 2758 N/cm^2	0 to 4000 psi
D60	Hydraulic oil pressure, gage	15-21	0 to 2758 N/cm^2	0 to 4000 psi
D66	Roll torque rate	16-41	-4 to 4 deg/min (orbit mode) -50 to 50 deg/min (ascent mode)	
D68	Pitch actuator position	15-3	-2.5° to 2.5°	
D69	Yaw actuator position	15-24	-2.5° to 2.5°	
D70	Control gas supply temperature,	15-42	171 to 367 K	-150° to 200° F
D72	Pitch gyro output	16-36	-5° to 5° (orbit mode) -10° to 10° (ascent mode)	
D73	Pitch torque rate	16-35	-10 to 10 deg/min (orbit mode) -200 to 200 deg/min (ascent mode)	
D74	Yaw gyro output	16-39	-5° to 5° (orbit mode) -10° to 10° (ascent mode)	
D75	Roll gyro output	16-42	-5° to 5° (orbit mode) -10° to 10° (ascent mode)	

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

[b]Events are indicated by a step change in telemetry voltage.

[d]Events are indicated by a transient pulse in telemetry voltage.

Measurement number	Measurement title	Channel[a]	Measurement range (low to high)	
			SI units	U.S. customary units
D83	Velocity meter accelerometer	14	0 to 2000 pulses/sec	
D86	Velocity meter cutoff switch	16-28	(b)	
D88	Velocity meter counter	14	Binary code (50 bits/sec)	
D129	Inertial reference package internal temperature	15-54	228 to 367 K	-50° to 200° F
D149	Gas valve current monitor (valves 1 to 6)	7	(e)	
D150	Gas valve current monitor (valves 1 and 5)	4		
D151	Gas valve current monitor (valves 1 and 3)	5		
D152	Gas valve current monitor (valves 4 and 6)	6		
BTL1	Radio guidance magnetron current monitor	13	(b)	
BTL2	Radio guidance combined events monitor	18	(b)	
BTL4	Radio guidance automatic gain control monitor	12	-70 to 0 dBm	
BTL5	Radio guidance steering relay monitor	16-30	(b)	
BTL6	Radio guidance regulated voltage monitor	16-19/49	22 to 30 V dc	
H47	C-band beacon receiver pulse rate	15-27	0 to 1600 pulses/sec	
H48	C-band transmitter pulse rate	15-28	0 to 1600 pulses/sec	

[a]The first number indicates the Inter-Range Instrumentation Group (IRIG) subcarrier channel used. The second number indicates the commutated position for the measurement. If no second number is indicated, the channel was used continuously for the designated measurement.

[b]Events are indicated by a step change in telemetry voltage.

[e]A unique voltage level is associated with any one, or a combination of, thrust valve firings.

APPENDIX C

ASCENT TRACKING AND DATA ACQUISITION

by Richard L. Greene and Richard E. Orzechowski

This appendix discusses the launch vehicle tracking and data acquisition coverage for the ascent phase of the SERT II mission. Coverage was provided by the Western Test Range (WTR), the Pacific Missile Range (PMR), the Eastern Test Range (ETR), the Air Force Satellite Control Facility (AFSCF), the NASA Manned Space Flight Network (MSFN), and the NASA Kennedy Space Center at Vandenberg Air Force Base (VAFB). These facilities provided seven radar stations, seven telemetry stations, and three real-time computer centers to support the launch vehicle data requirements. Also the tracking radar for the radio guidance system, located at VAFB, provided support during early ascent.

The launch vehicle trajectory during the ascent phase and during the early portion of the first orbit is presented in figure C-1. Appendix E presents the tracking and data acquisition coverage during the in-orbit phase of the SERT II mission.

TELEMETRY DATA

Telemetry signals from the Thorad-Agena launch vehicle were recorded on magnetic tape during all Thorad and Agena powered phases and during initiation of residual propellant dump. The data recorded on magnetic tape were used for postflight analysis of the launch vehicle performance.

Real-time monitoring at the launch site telemetry stations of all Thorad and Agena telemetry measurements permitted verification of all flight events and quick-look evaluation of launch vehicle performance from lift-off until just before Agena engine first cutoff. The range instrumentation ship Swordknot monitored all the Agena first powered phase, including Agena engine first cutoff. The MSFN station at Tananarive, Malagasy Republic, provided real-time retransmission of selected Agena telemetry measurements to the NASA telemetry station at VAFB, and to the AFSCF at Sunnyvale, California, to permit verification of Agena engine second start, second cutoff, and initiation of residual oxidizer dump and residual fuel dump.

The occurrence of all significant flight events was identified by the supporting remote telemetry stations and voice reported to VAFB via radio and cable communication circuits. The time of occurrence was provided in near real-time.

All telemetry stations supporting the launch vehicle during the ascent phase of the SERT II mission were operational, and received and recorded data. The data retransmitted from Tananarive were received satisfactorily at the AFSCF but were not received at the NASA telemetry station. Figure C-2 shows the coverage provided by each telemetry station.

RADARD DATA

C-band radar data (time, elevation, azimuth, and range) were provided for both real-time operations and postflight analysis. The real-time radar data were provided for monitoring the launch vehicle flight performance for range safety purposes, and for assisting the downrange stations in acquiring track of the vehicle. These data were also used for computation of orbital parameters and insertion conditions at the end of each Agena powered operation, and final orbit parameters after the Agena residual propellant dump. Final orbit parameters were also required (to refine acquisition data for the ground stations) for in-orbit operations (see appendix E).

Three real-time computer centers (table C-1) provided calculations for range safety, downrange station acquisition information, and descriptive parameters of the Agena intermediate orbits and the final orbit achieved. An exchange of real-time radar data between networks permitted redundant computer support, as illustrated in table C-1. Figure C-3 presents the specific radar coverage provided by each station.

TABLE C-1. - COMPUTER SUPPORT OF SERT II

Data source	Flight interval	Real-time computer	Type of support
Western Test Range radar stations	Lift-off through Agena engine first start	WTR	Range safety displays
Tananarive radar station (MSFN)	Before Agena engine second operation through the initiation of Agena fuel dump	ETR, MSFN	Agena transfer orbit and circular orbit calculations; acquisition information for subsequent tracking stations
Western Test Range radar stations and Hawaii radar station (MSFN)	Agena first orbital pass	ETR, MSFN	Final orbit calculations; refining of the acquistion information for ground stations

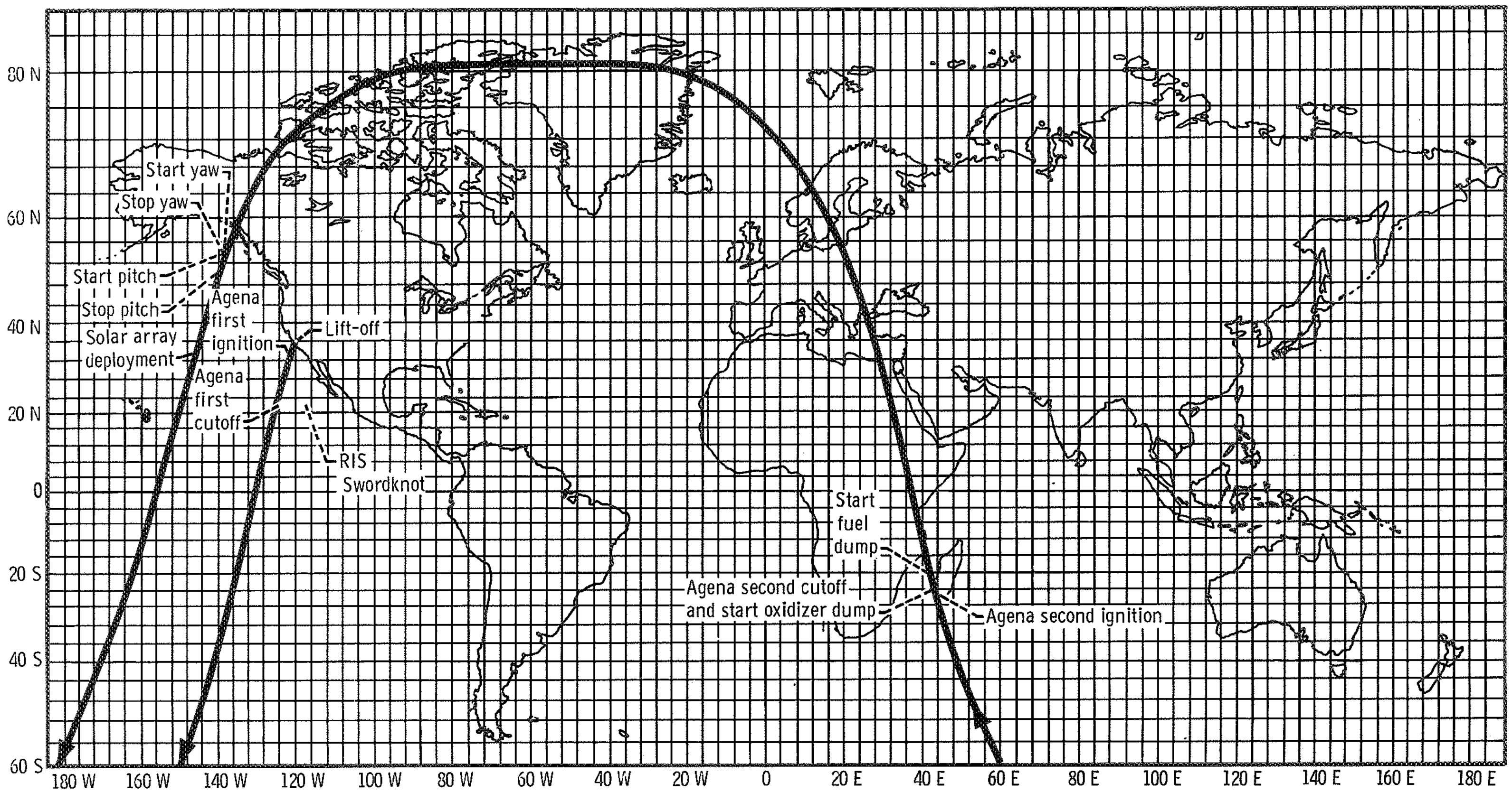


Figure C-1. - Ground track of ascent and early portion of orbital phase, SERT II.

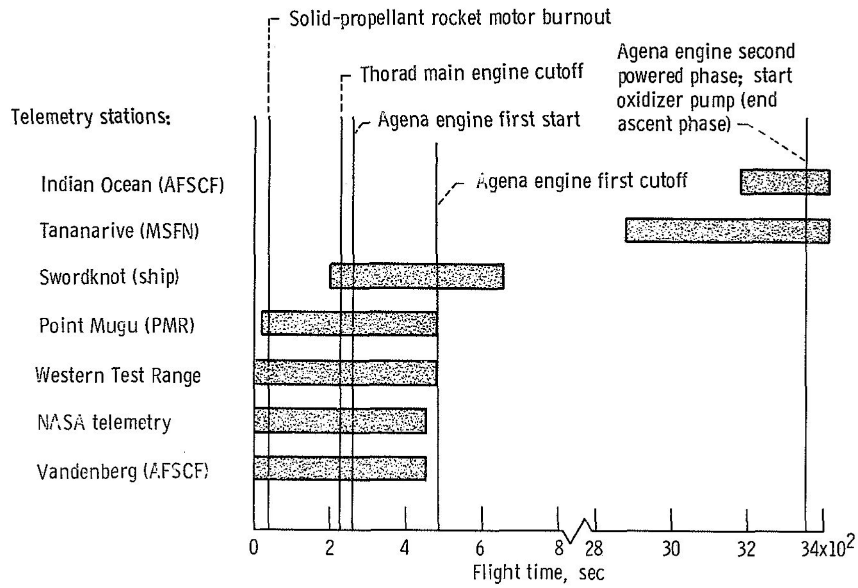


Figure C-2. - Launch vehicle ascent telemetry coverage, SERT II.

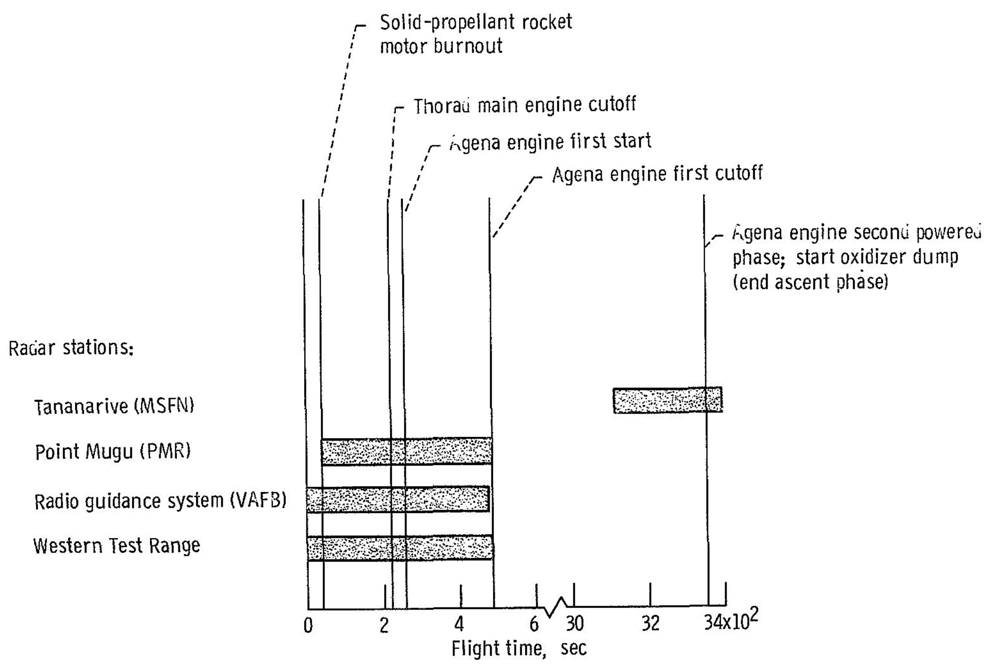


Figure C-3. - Launch vehicle ascent radar coverage, SERT II.

APPENDIX D

VEHICLE FLIGHT DYNAMICS

by Dana H. Benjamin

Flight dynamics data were obtained from three accelerometers installed on the forward end of the Agena guidance module in the Agena forward section. A summary of dynamic instrumentation locations and characteristics is presented in figure D-1.

Table D-1 presents the actual flight times at which significant dynamic disturbances were recorded and table D-2 shows the maximum acceleration levels and corresponding frequencies recorded at these times. All acceleration levels are shown in g's zero-to-peak.

Data traces of the dynamic environment recorded by all three instruments for the events summarized in table D-2 are presented in figures D-2 to D-15.

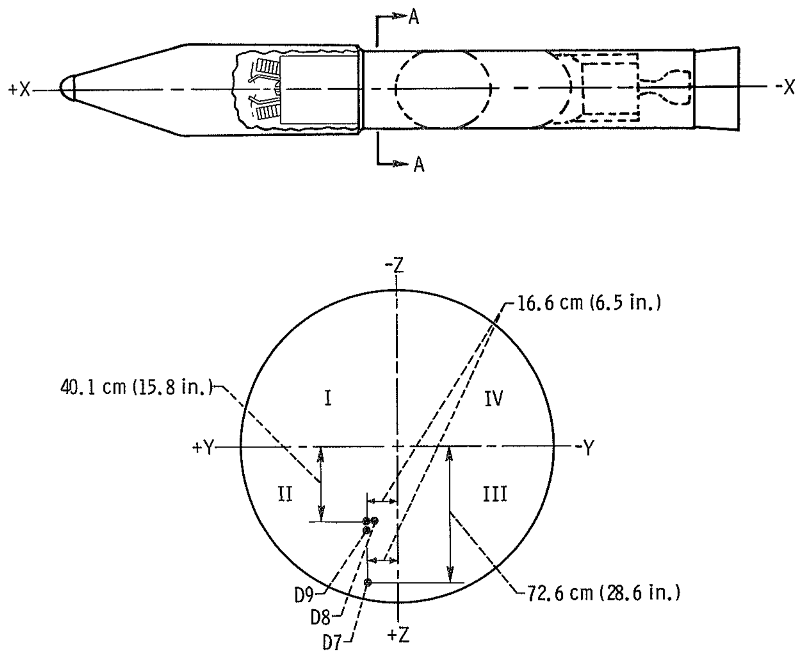
TABLE D-1. - SUMMARY OF DYNAMIC DISTURBANCES, SERT II

Event causing disturbance	Time of dynamic disturbance, sec after lift-off
Lift-off	-0.19
Transonic region	36.80
Solid-propellant rocket-motor-case jettison	102.89
Peak longitudinal oscillation (POGO)	210.75
Thorad main engine cutoff	224.72
Agena horizon sensor fairing jettison	233.00
Thorad-Agena separation	240.26
Agena engine first start	260.13
Shroud separation	268.95
Agena engine first cutoff	492.29
Agena engine second start	3359.06
Agena engine second cutoff	3363.70
Firing of 90° horizon sensor squibs	6032.03
Release of solar arrays	6352.56

TABLE D-2. - SUMMARY OF DYNAMIC ENVIRONMENT, SERT II

Event causing disturbance	Time of dynamic disturbance, sec after lift-off	Accelerometer					
		Channel 8		Channel 9		Channel 11	
		Measurement					
		D8 Lateral (Y-axis)		D9 Lateral (Z-axis)		D7 Longitudinal (X-axis)	
		g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz	g's (zero to peak)	Frequency, Hz
Lift-off	-0.19	0.53	42	0.08	100	0.3	150
Transonic region	36.80	.43	46	.23	86	.5	100
Solid-propellant rocket-motor-case jettison	102.89	.23	46	.07	43	(a)	(a)
Peak longitudinal oscillation (POGO)	210.75	.33	45	.09	33	3.95	17.7
Thorad main engine cutoff	224.72	.32	56	.05	52	.3	20
Agena horizon sensor fairing jettison	233.00	.52	57	.49	80	1.9	280
Thorad-Agena separation	240.26	.12	44	.06	100	.3	200
Agena engine first start	260.13	.47	48	.14	44	.3	65
Shroud separation	268.95	.65	43	.25	70	1.7	260
Agena engine first cutoff	492.29	.87	59	.28	79	.7	120
Agena engine second start	3359.06	1.0	59	.25	87	.8	89
Agena engine second cutoff	3363.70	1.3	58	.37	83	.97	180
Firing of 90° horizon sensor squibs	6032.03	.42	54	.07	55	.4	330
Release of solar arrays	6352.56	.27	46	.10	46	.3	160

[a]No detectable response.



Section A-A: Station 255

Channel	Measurement			Frequency response, Hz	Range, g's	Transducer sensitive axis
	Description	Number	Station number			
8	Y-axis acceleration	D8	255	0 to 45	± 1.5	Y-direction
9	Z-axis acceleration	D9	255	0 to 60	± 1.5	Z-direction
11	X-axis acceleration	D7	255	0 to 110	- 4 to +12	X-direction

Figure D-1. - Dynamic instrumentation location, SERT II.

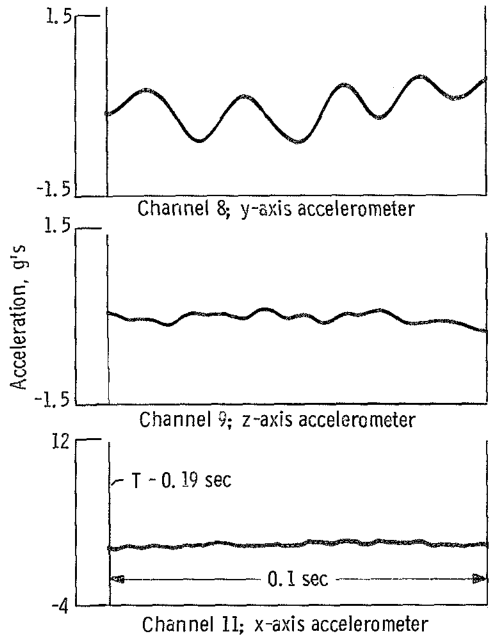


Figure D-2. - Dynamic data near lift-off, SERT II.

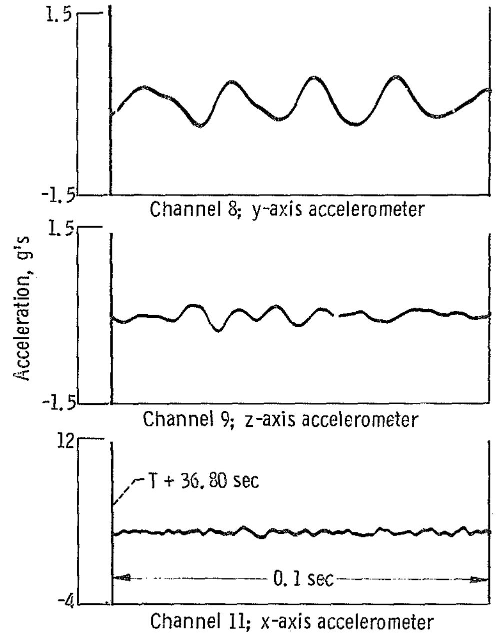


Figure D-3. - Dynamic data during transonic region of flight, SERT II.

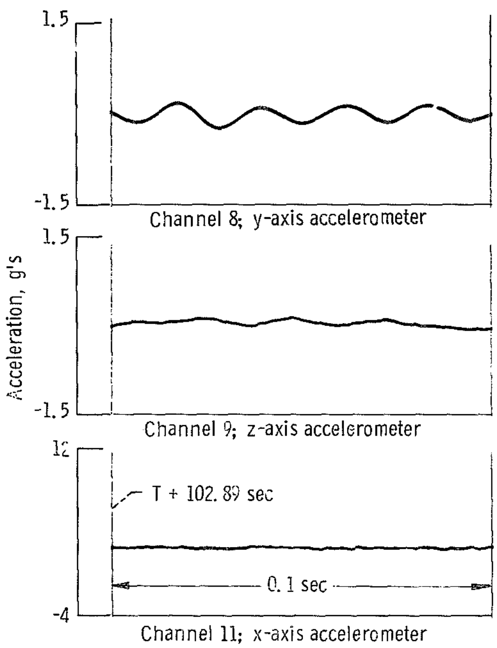


Figure D-4. - Dynamic data at solid-propellant rocket-motor-case jettison, SERT II.

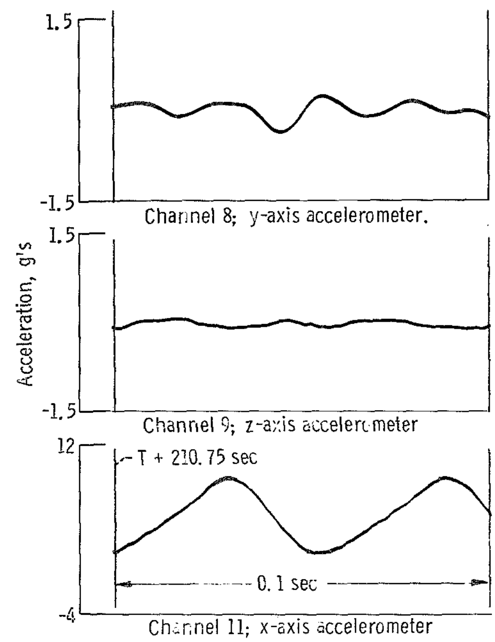


Figure D-5. - Dynamic data at peak longitudinal oscillation (POGO), SERT II.

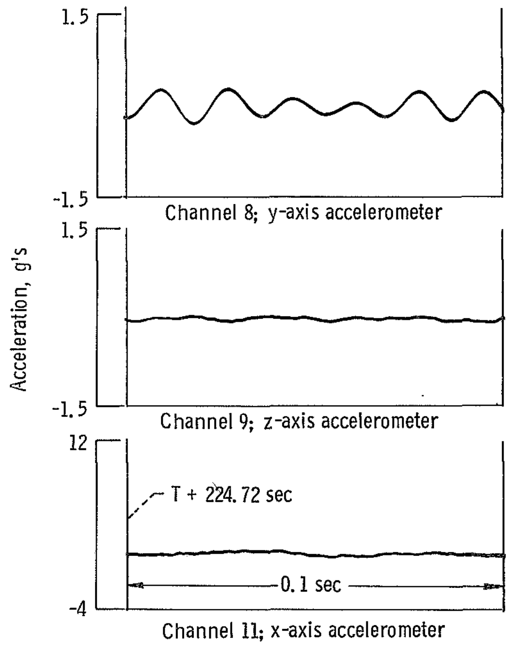


Figure D-6. - Dynamic data near Thorad main engine cutoff, SERT II.

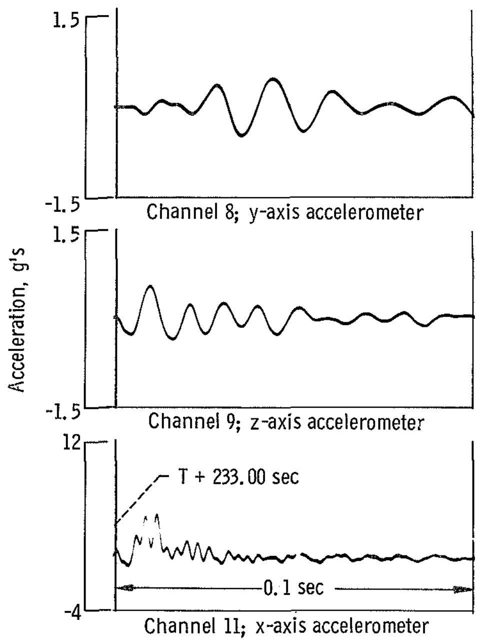


Figure D-7. - Dynamic data at horizon sensor fairing jettison, SERT II.

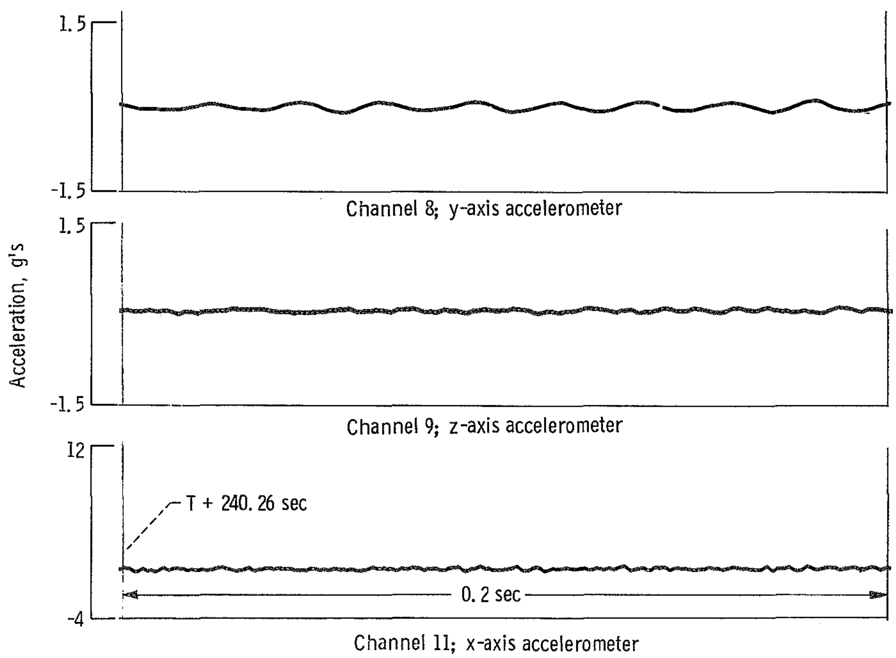


Figure D-8. - Dynamic data near Thorad-Agena separation, SERT II.

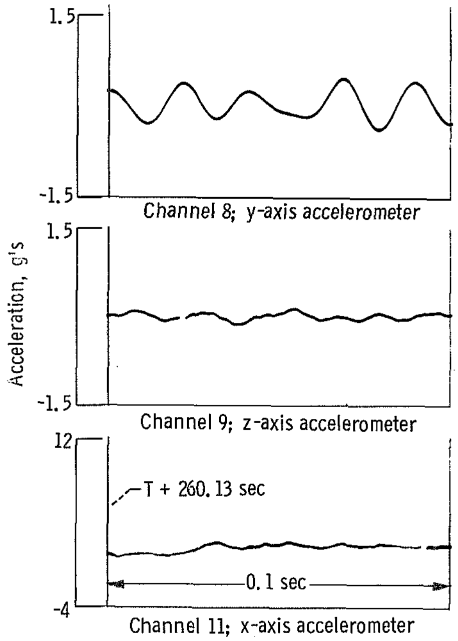


Figure D-9. - Dynamic data near Agena engine first start, SERT II.

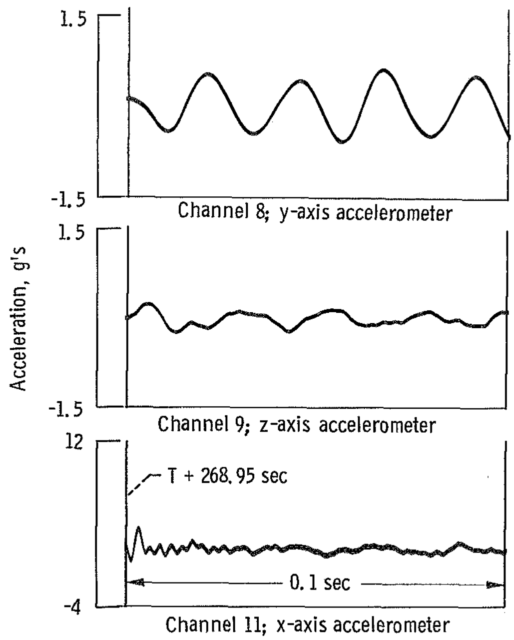


Figure D-10. - Dynamic data at shroud separation, SERT II.

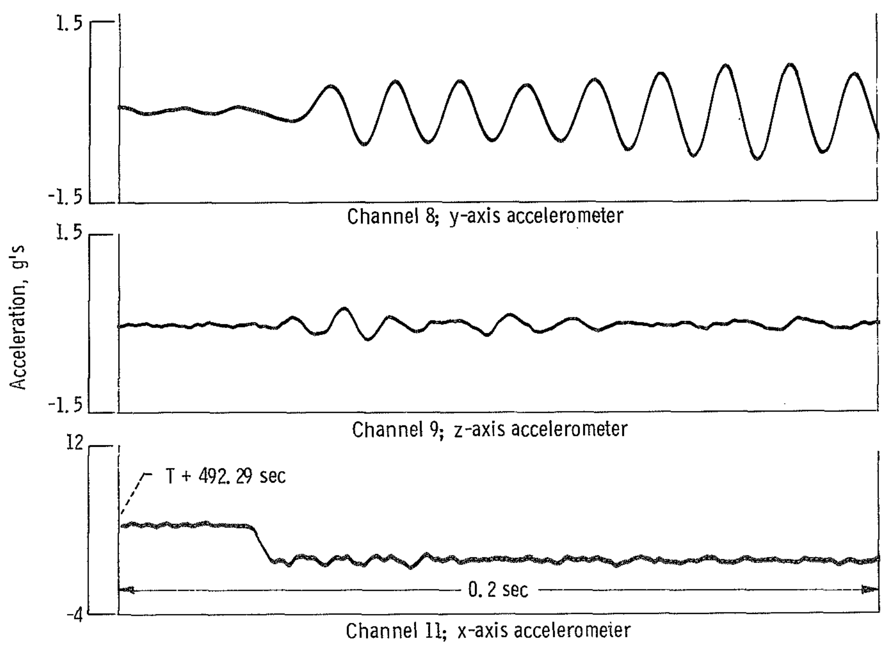


Figure D-11. - Dynamic data at Agena engine first cutoff, SERT II.

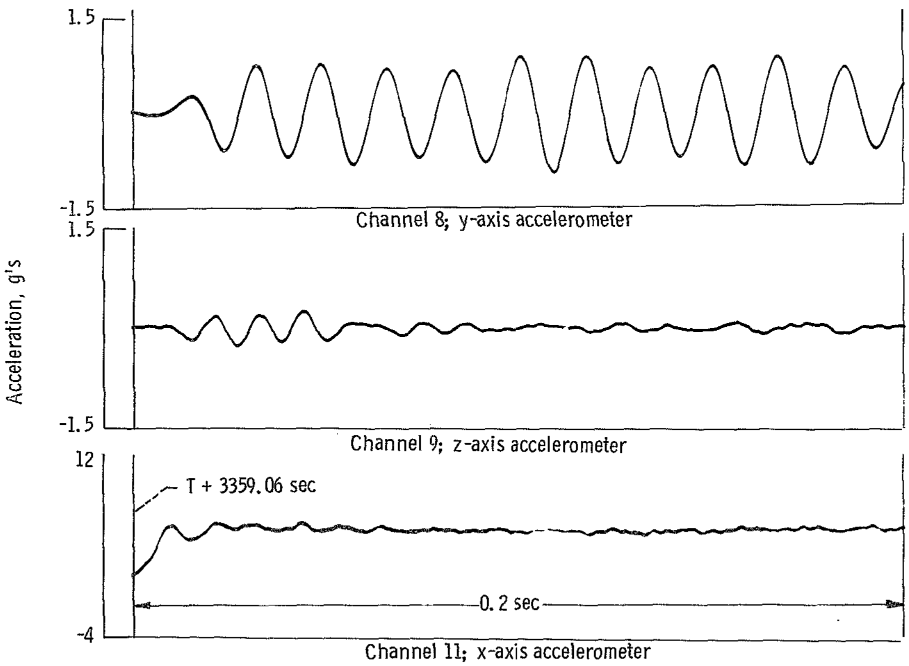


Figure D-12. - Dynamic data near Agena engine second start, SERT II.

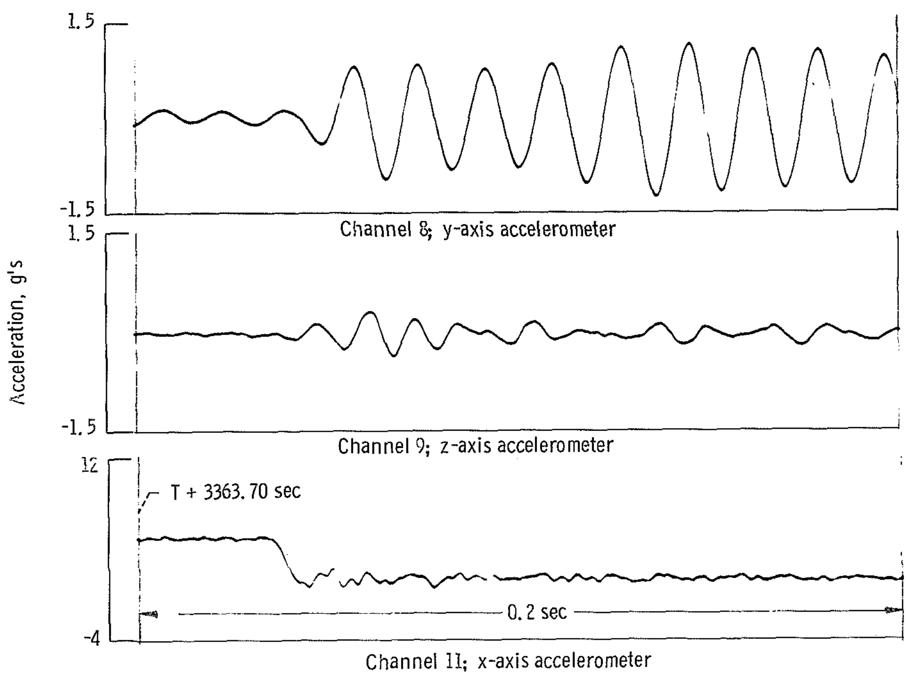


Figure D-13. - Dynamic data at Agena engine second cutoff, SERT II.

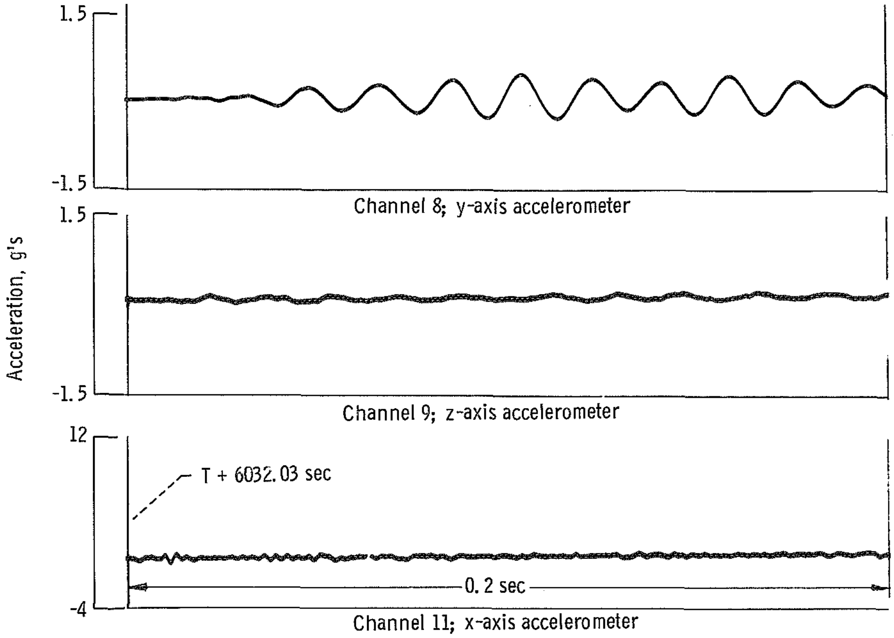


Figure D-14. - Dynamic data at firing of 90° horizon sensor squibs, SERT II.

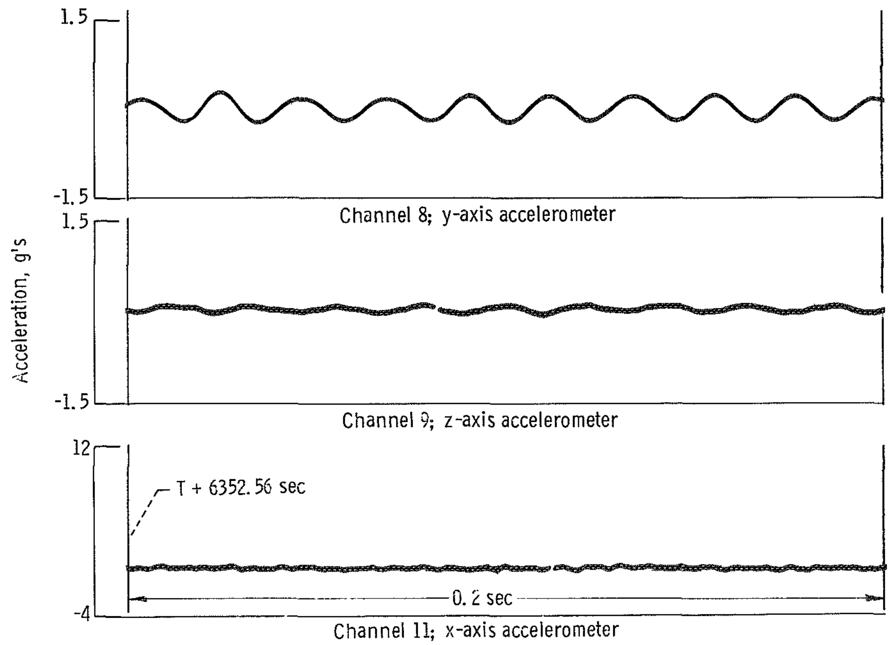


Figure D-15. - Dynamic data near release of solar arrays, SERT II.

APPENDIX E

IN-ORBIT-PHASE TRACKING AND DATA ACQUISITION

by Richard L. Greene and Richard E. Orzechowski

The U.S. Air Force and NASA provided tracking and data acquisition for the in-orbit phase of operation. During these operations a NASA/Agena-contractor team evaluated the data and transmitted instructions for Agena ground commands to a NASA SERT II Control Center. The SERT II Control Center issued command directions to remote NASA facilities, where these commands were transmitted to the Agena.

The following paragraphs describe the tracking and data acquisition facilities and their operation during the orbital phase. Figure E-1 shows the interconnection of tracking and data acquisition facilities. Figure E-2 presents an earth track of the orbital vehicle for orbits 0 to 18. Figure E-3 shows telemetry coverage for the first orbit. Table E-1 shows USAF in-orbit telemetry coverage for orbits 1 to 30, and table E-2 shows NASA in-orbit telemetry coverage for orbits 1 to 19.

TELEMETRY DATA

U.S. Air Force Satellite Control Facility (AFSCF)

The AFSCF facility, which received, and processed Agena telemetry data, consists of a world-wide network of seven remote tracking stations and a control center. This control center is the Air Force Satellite Test Center (STC) located in Sunnyvale, California. The seven remote tracking stations are located in Alaska (Kodiak Tracking Station), in California (Vandenberg Tracking Station), in New Hampshire (New Hampshire Tracking Station), on Hawaii (Hawaii Tracking Station), on Guam (Guam Tracking Station), on Mahe Island (Indian Ocean Station), and on the North American continent (Station OL-5). Figure E-4 shows a block diagram of the major functional components of the AFSCF network.

Each remote tracking station has data, voice, and teletype links to the STC. The data links couple computer data processing equipment at the remote sites with computer data processing equipment in the STC to permit real-time display of Agena telemetry data by digital printouts of telemetry voltages and engineering units.

In addition to the standard AFSCF data processing and digital display of Agena telemetry data as described in the preceding paragraphs, four of the AFSCF remote tracking stations supplied Agena selected measurements in an analog form. NASA supplied processing equipment and special data circuits in the STC to permit real-time analog display of Agena selected measurements. A NASA/Agena-contractor technical analysis team was located in the STC.

NASA Manned Space Flight Network (MSFN)

The MSFN support consists of a Network Control Center at the NASA Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, and remote tracking stations located throughout the world. The MSFN supplemented the AFSCF Agena telemetry support by receiving, recording, and processing data for remote site display, and by real-time retransmission of selected measurements in analog form. Five of these remote tracking sites located at Tananarive, Malagasy Republic; Carnarvon, Australia; Hawaii; Guam; and the Canary Islands were used for the SERT II mission. The data values at the remote sites were voice reported to the NASA telemetry station at WTR and relayed from WTR to the STC. Figure E-5 diagrams the MSFN support configuration for SERT II.

NASA Telemetry Stations

The Agena telemetry support was also provided by NASA Kennedy Space Center (KSC) stations at the Eastern Test Range (ETR) and the Western Test Range (WTR). These stations received, recorded, and processed data for on-site display. The ETR station also retransmitted selected measurements in analog form to the STC and to the WTR station. The WTR station displayed in real time the selected analog measurements which were retransmitted from the MSFN stations and from the ETR station. The WTR station had voice contact with the MSFN, the ETR station, and the technical analysis team at the STC. Figure E-5 also shows the KSC support configuration for SERT II.

SERT II COMMAND LINK

SERT II Control Center (SCC)

The SCC, at the NASA Lewis Research Center, Cleveland, Ohio, collected spacecraft telemetry data and issued direction for all SERT II commands, including Agena commands, during in-orbit operations (see fig. E-1). The SCC was in voice contact with the technical analysis team at the Air Force STC.

NASA Satellite Tracking and Data Network (STADAN)

The STADAN, which provided tracking, data acquisition, and command transmittal to the SERT II, consits of a world-wide network and remote tracking stations at Fairbanks, Alaska; Rosman, N.C.; Orroral, Australia; and Winkfield, England. The SCC was in voice contact with these remote tracking stations. Table E-3 presents STADAN station coverage for orbits 2 to 19.

AGENA COMMAND OPERATION

The technical analysis team of NASA/Agena-contractor personnel was located at the Air Force STC. They evaluated the Agena digital and analog data and originated Agena ground-command decisions and instructions. These instructions were voice transmitted to the SCC. The SCC then issued command direction to the appropriate STADAN tracking station. The STADAN remote tracking station, on receipt of direction from the SCC, transmitted the command to the Agena. All facets of this complex and world-wide operation were successful.

A prerequisite for sending ground commands to the Agena via the SERT II link was that the coverage of both a STADAN station (for sending the command) and an AFSCF station (for receiving Agena telemetry data) must overlap. This enabled determination of Agena status before and after the issuance of ground commands. The stations that provided the required overlapping coverage are listed in the following table:

Command	Orbit	Station	
		STADAN	AFSCF
1	8	Fairbanks, Alaska	Kodiak, Alaska
2	13	Rosman, N. C.	New Hampshire
1 (repeat)	15	Fairbanks, Alaska	Kodiak, Alaska
3	17	Fairbanks, Alaska	Kodiak, Alaska

RADAR DATA

Agena C-band radar data for the in-orbit phase of the flight were provided by the Tananarive, WTR, and Hawaii radar stations. Tananarive radar provided data during the second powered phase and through initiation of Agena propellant dump. These data were used for calculation of the Agena circular orbit and to update acquisition information for use by the telemetry stations. The WTR and Hawaii radars provided data during the first orbit for use in calculating the final orbital parameters, which were then used for precise prediction of telemetry coverage. Figure E-6 shows the in-orbit radar coverage.

TABLE E-1. - AFSCF AGENA TELEMETRY COVERAGE,[a] SERT II

Orbit	Kodiak test site		Vandenberg test site		New Hampshire test site		OL-5		Guam test site		Hawaii test site		Indian Ocean site		Date
	AOS[b]	LOS[c]	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	
1	04:19:18	04:37:00									04:25:06	04:40:27			Feb. 4, 1970 (Gmt)
2	06:03:17	06:20:53													
3	07:47:05	08:01:48					07:37:57	07:55:09							
4					09:14:48	09:29:58	09:22:09	09:39:03							
5					10:56:26	11:14:04	11:07:46	11:23:31							
6	12:51:17	13:06:10					12:54:04	13:08:16							
7	14:32:29	14:49:56													
8	16:06:58	16:24:13					16:27:53	16:40:09			16:08:53	16:23:25			
9	18:05:36	18:17:20					18:14:49	18:28:15			17:51:09	18:05:32			
10							20:01:00	20:14:50	19:35:36	19:51:50					
11					21:57:21	22:11:40	21:46:04	22:01:40	21:18:41	21:35:39					
12					23:39:50	23:57:40	23:30:41	23:47:07							
13			01:29:18	01:45:29	01:24:17	01:38:36									Feb. 5, 1970 (Gmt)
14	03:07:20	03:22:45	03:12:27	03:30:52									02:29:24	02:47:44	
15	04:51:05	05:09:13									05:01:28	05:19:58	04:14:45	04:29:58	
16	06:35:02	06:52:08					06:26:13	06:11:50							
17	08:27:05	08:32:39							08:34:08	08:53:10					
18					09:45:15	10:02:15	09:54:12	10:11:15							
19					11:28:40	11:45:45	11:40:12	11:55:35							
20			13:12:40	13:30:10											
21			14:56:36	15:13:32											
22							17:00:27	17:13:00							
23							18:47:28	19:10:27							
24									20:06:25	20:24:05					
25									21:51:42	22:06:10					
26					00:11:39	00:29:01									Feb. 6, 1970 (Gmt)
27													01:23:20	01:33:30	
28			03:37:32	04:01:08											
29	05:22:56	05:41:03													
30	07:06:40	07:22:37													
31	08:41:46	08:58:20													

[a] All times in Greenwich mean time (Gmt).
[b] Aquisition of signal.
[c] Loss of signal.

TABLE E-2. - NASA AGENA TELEMETRY COVERAGE,[a] SERT II

Orbit	NASA telemetry stations				Manned Space Flight Network stations										Date
	Western Test Range		Eastern Test Range		Guam		Hawaii		Carnarvon		Canary Island		Tananarive		
	AOS[b]	LOS[c]	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	AOS	LOS	
1	04:26:20	04:37:40					04:30:03	04:47:59			05:39:00	05:53:10	05:22:29	05:32:09	Feb. 4, 1970 (Gmt)
2							06:13:21	06:30:49			07:21:04	07:39:00			
3					08:03:29	08:20:35									
4					09:47:37	10:03:03			09:59:30	10:17:00					
5			10:53:12	11:10:24					11:43:00	11:57:00					
6	12:42:00	12:58:00	12:38:20	12:53:17									13:30:30	13:45:00	
7	14:25:40	14:41:52											15:12:11	15:29:42	
8	16:14:45	16:18:00					16:06:29	16:24:34							
9							17:50:46	18:07:33			18:31:50	18:47:30			
10									21:12:26	21:23:11	20:14:55	20:31:30			
11			22:04:09	22:13:36	21:23:11	21:35:26			22:52:51	23:12:00					
12			23:44:26	00:02:09					00:38:00	00:51:28					Feb. 5, 1970 (Gmt)
13	01:29:49	01:44:10	01:29:19	01:43:26									02:24:30	02:42:45	
14	03:12:30	03:29:26					03:21:49	03:32:03					04:09:42	04:26:27	
15	04:58:20	05:08:47					05:00:00	05:20:27							
16							06:46:14	07:00:55			06:10:20	06:26:51			
17					08:35:00	08:51:00					07:53:40	08:09:45			
18			09:44:06	09:57:00					08:80:00	09:04:00					
19															

[a]All times in Greenwich mean time (Gmt).
[b]Aquisition of signal.
[c]Loss of signal.

TABLE E-3. - STADAN SPACECRAFT TELEMETRY AND COMMAND COVERAGE,[a] SERT II

Orbit	Winkfield		Fairbanks		Orroral		Rosman		Date
	AOS[b]	LOS[c]	AOS	LOS	AOS	LOS	AOS	LOS	
2	05:43:34	06:01:40	06:02:40	06:18:25	06:35:10	06:49:29			Feb. 4, 1970 (Gmt)
3	07:29:44	07:45:08	07:46:12	08:01:20	08:18:24	08:33:56			
4			09:28:30	09:42:55					
5			11:10:00	11:24:30			10:54:58	11:12:01	
6			12:52:50	13:01:00			12:39:40	12:55:02	
7			14:35:45	14:50:40					
8			16:20:10	16:34:45					
9	18:22:27	18:40:05	18:06:20	18:19:30	19:21:46	19:35:45			
10			20:06:20	20:23:37	21:05:06	21:21:09			
11	21:50:27	22:03:46							
12							23:42:47	00:00:37	
13							01:27:26	01:42:55	Feb. 5, 1970 (Gmt)
14	02:52:18	03:05:28	03:06:50	03:19:35					
15	04:32:16	04:49:33	04:51:05	05:06:00					
16	06:15:53	06:33:24	06:34:10	06:50:25	07:06:11	07:21:40			
17			08:17:40	08:32:25	08:49:31	09:05:18			
18			09:59:50	10:13:45			09:45:00	09:59:00	
19			11:41:15	11:55:50			11:26:29	11:44:10	

[a]All times in Greenwich mean time (Gmt).
[b]Aquisition of signal.
[c]Loss of signal.

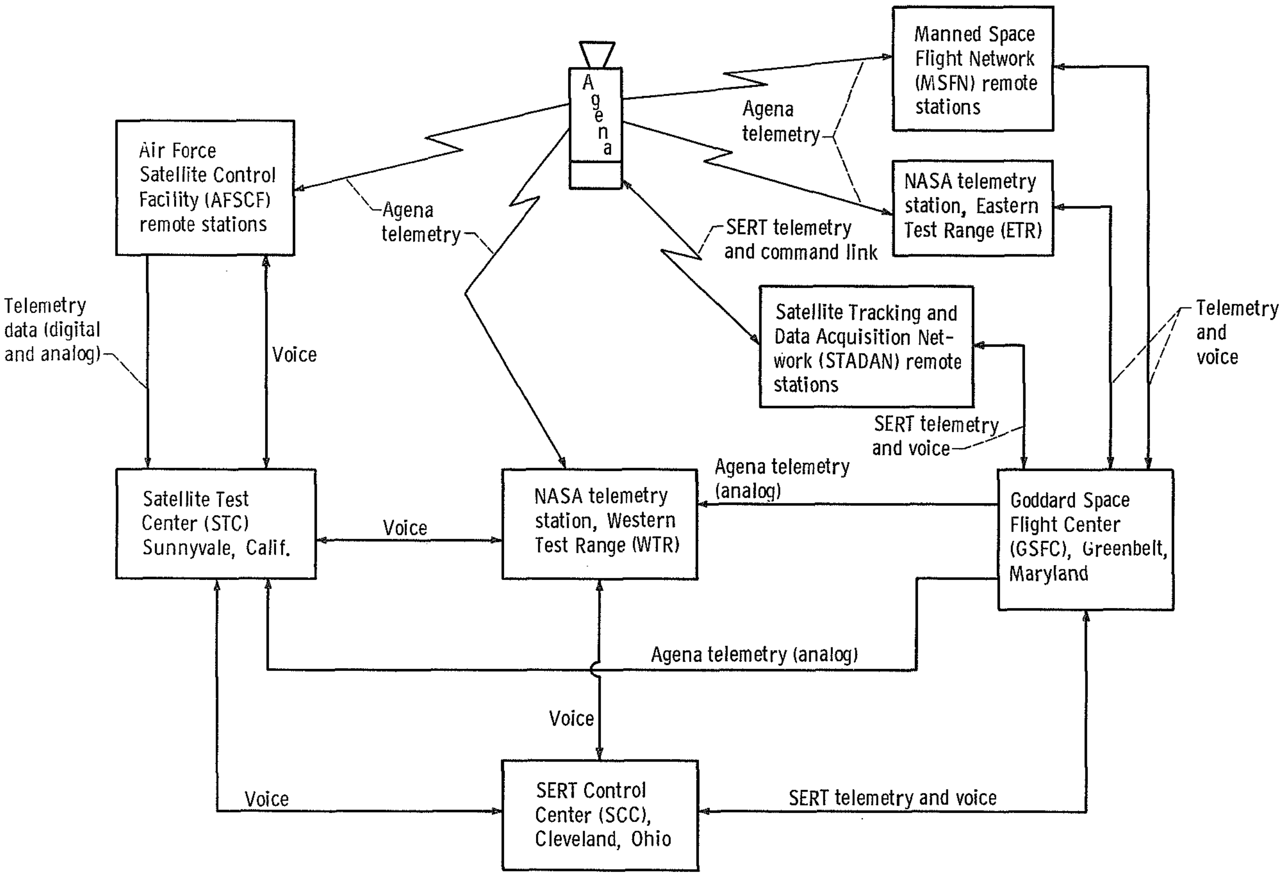


Figure E-1. - Orbital phase tracking and data acquisition facilities, SERT II.

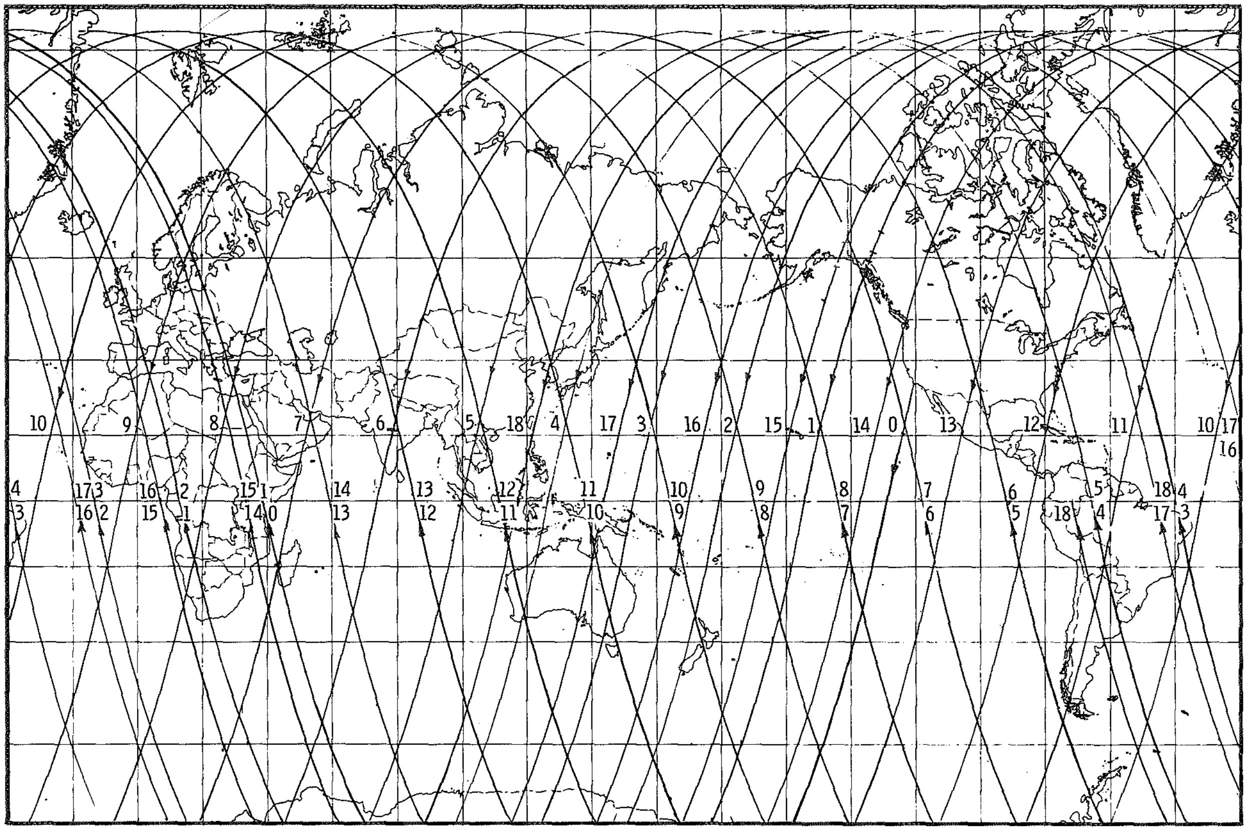


Figure E-2. - Orbit vehicle earth track, SERT II.

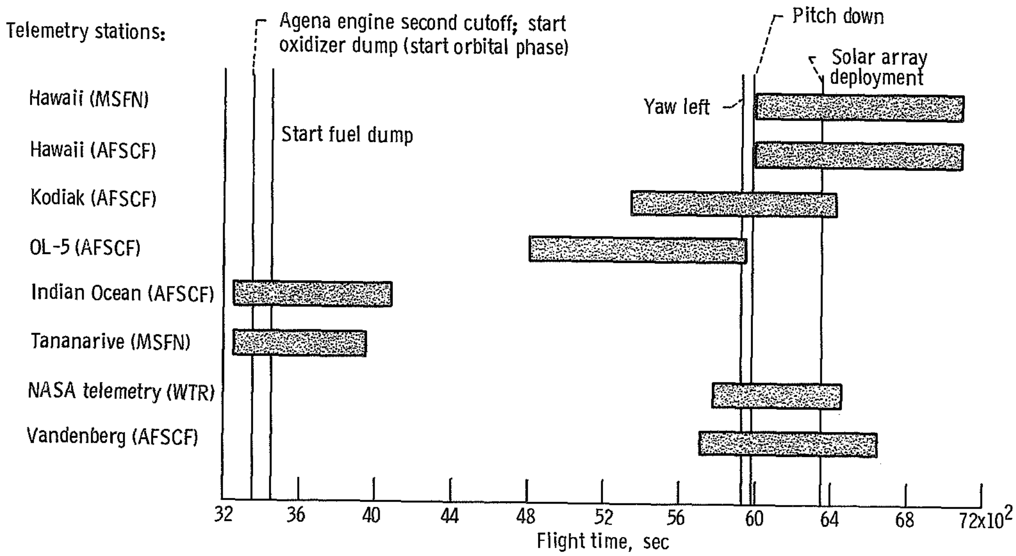


Figure E-3. - Agena telemetry coverage for orbit 1, SERT II.

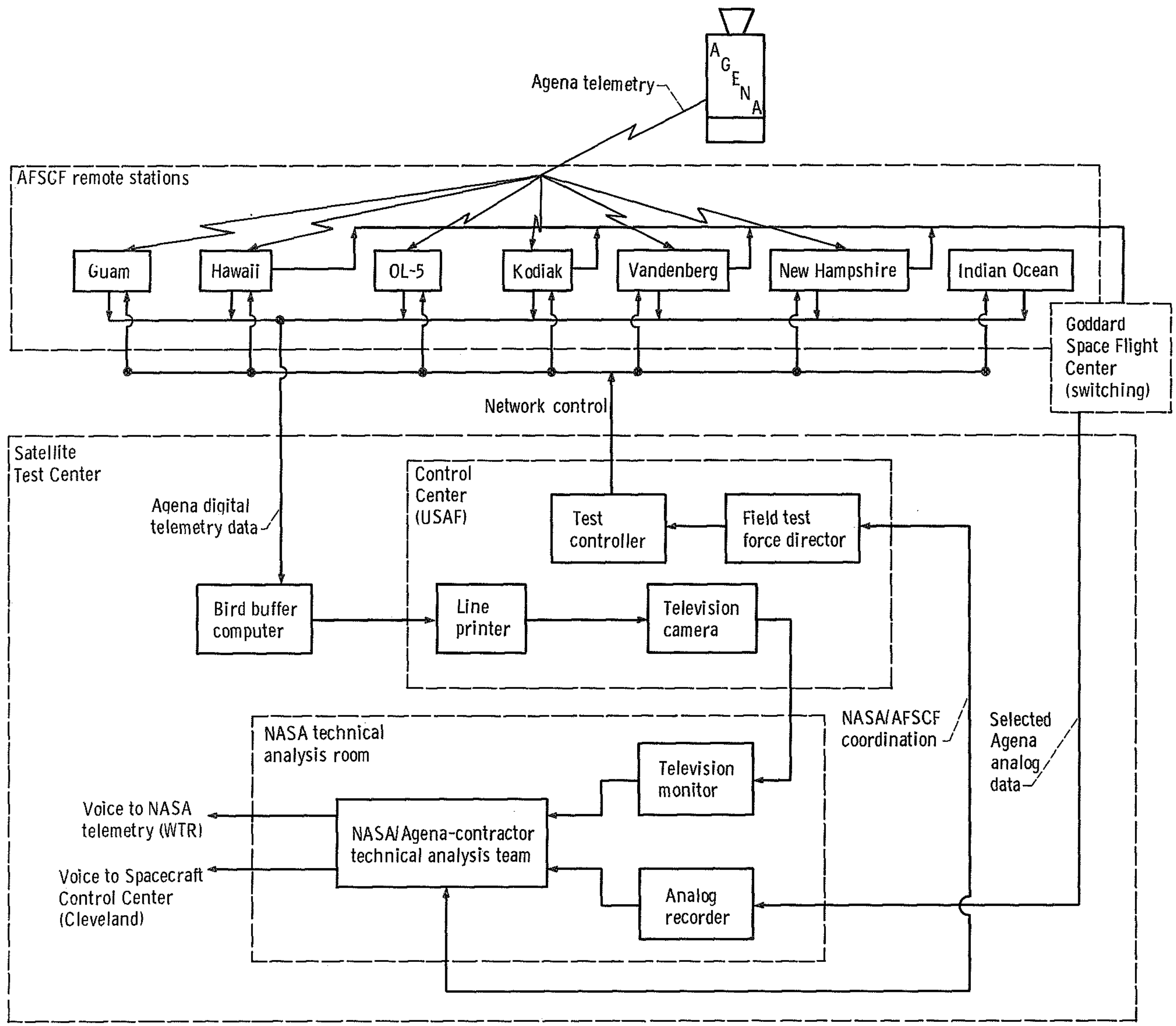


Figure E-4. - Air Force Satellite Control Center (AFSCF) support facilities, SERT II.

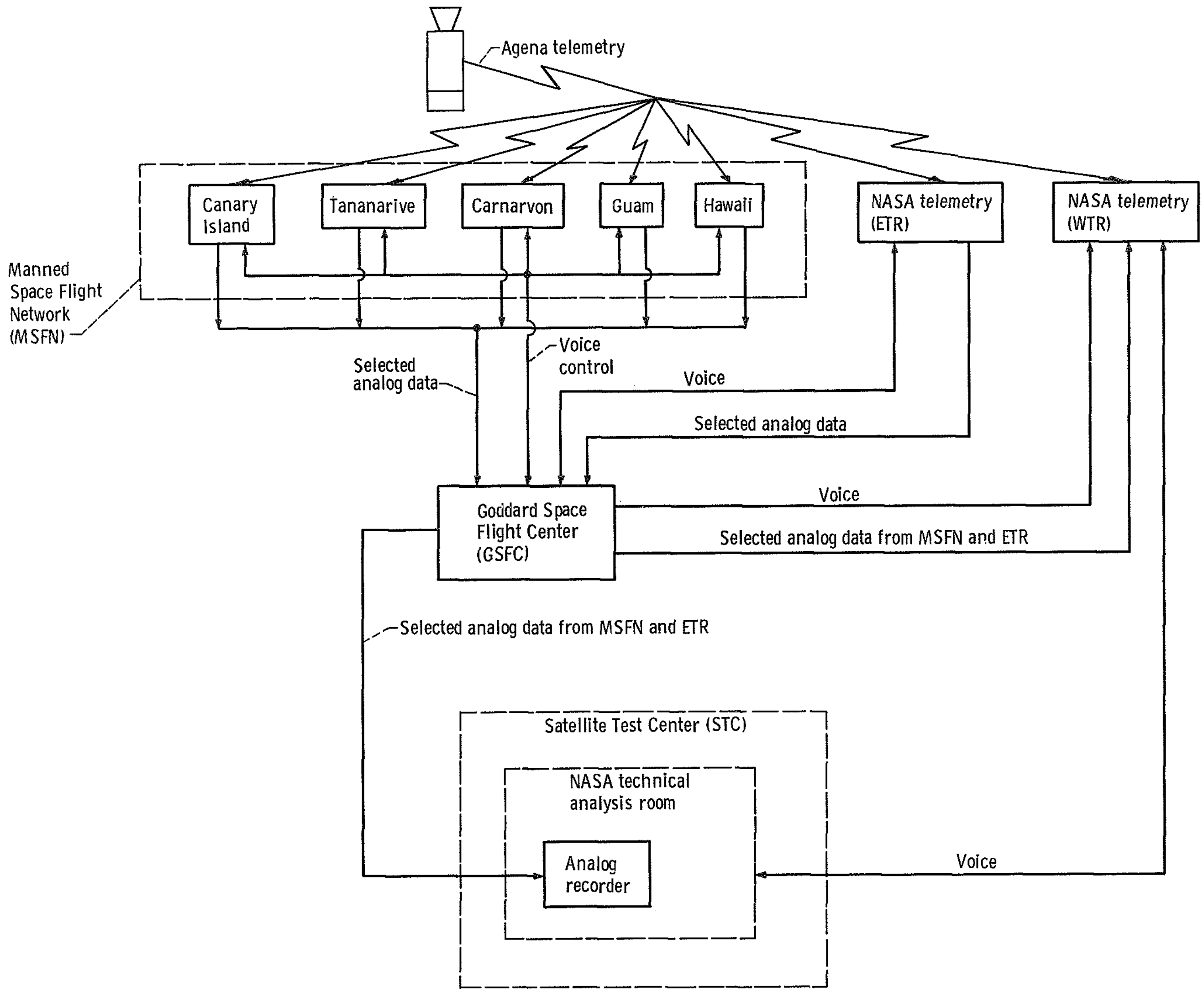


Figure E-5. - NASA support facilities, SERT II.

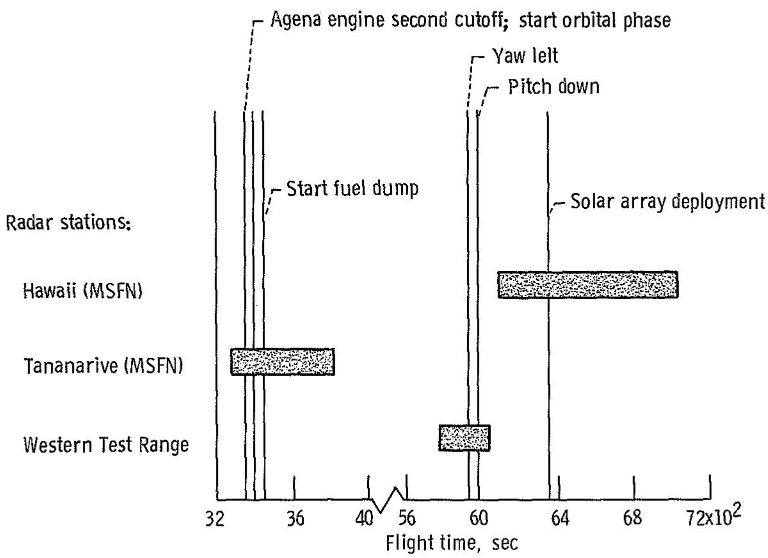


Figure E-6. - Agena radar coverage for orbit 1, SERT II.

APPENDIX F

VEHICLE TEMPERATURES

by C. Robert Finkelstein

Ascent and orbital temperature data were obtained from nine temperature transducers at various locations on the Agena vehicle. Table F-1 presents the telemetry channel, the measurement number and description, the range of temperature expected, the orbit during which the temperature stabilized, and the actual stabilized temperature for each transducer. The temperature data are also presented in detail in figures F-1 to F-6.

TABLE F-1. - SUMMARY OF AGENA VEHICLE

TEMPERATURES, SERT II

Channel	Measurement description	Predicted temperature range		Actual stabilized temperature		
		K	°F	Orbit	K	°F
15-39	+Z-Axis thrust valve cluster (D46)	317 to 339	110 to 150	6	[a]356	[a]180
15-36	-Z-Axis thrust valve cluster (D47)	239 to 261	-30 to 10	9	248	-15
15-47	Right horizon sensor head (D54)	306 to 328	90 to 130	10	335	143
15-46	Left horizon sensor head (D55)	306 to 328	90 to 130	9	334	141
15-14	Inverter (C21)	286 to 317	55 to 110	21	330	134
15-42	Control gas supply (D70)	267 to 284	20 to 50	[b]8	[b]284	[b]50
15-54	Inertial reference package (D129)	333 to 339	140 to 150	16	345	160
15-8	Oxidizer pump inlet (B32)	(c)	(c)	10	314	105
15-6	Fuel pump inlet (B31)	(c)	(c)	13	316	109

[a]Temperature based on extrapolation of calibration curve.
[b]Before gas dump.
[c]No temperature predictions.

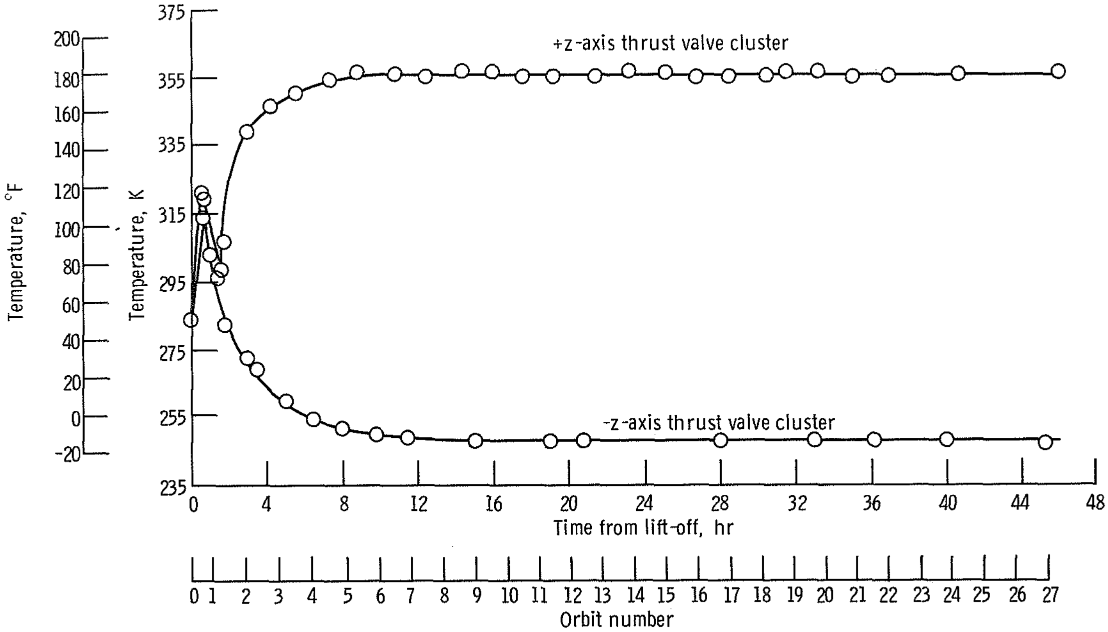


Figure F-1. - Thrust-valve-cluster temperature histories, SERT II.

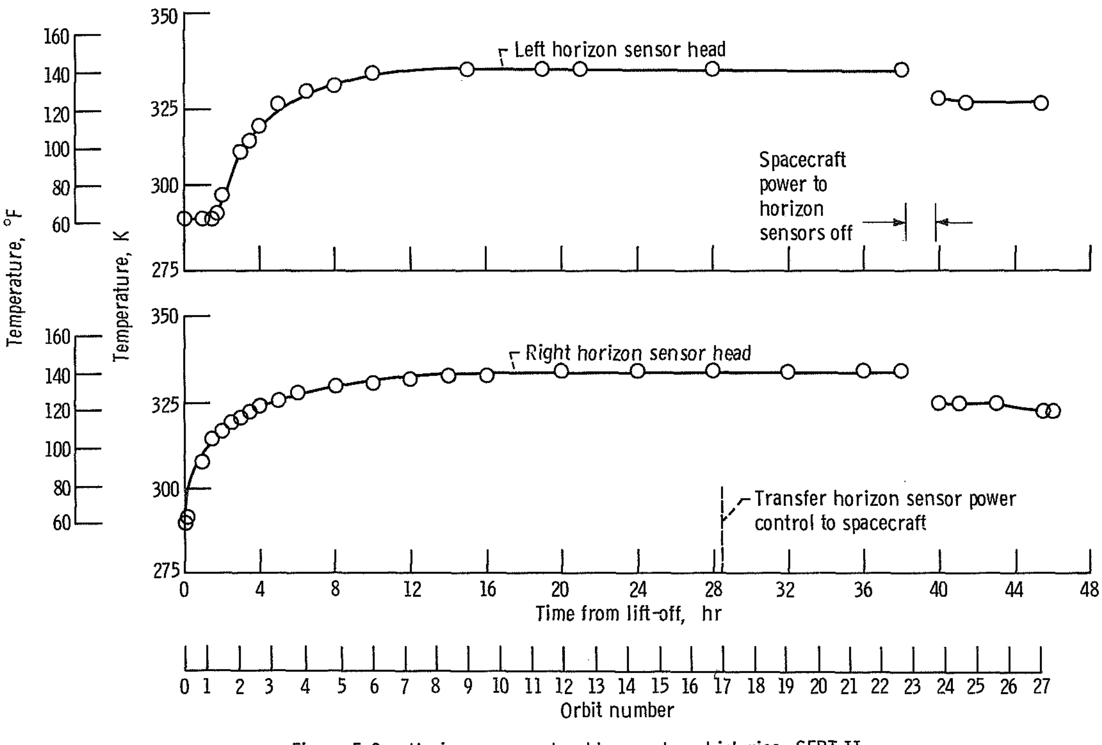


Figure F-2. - Horizon-sensor-head temperature histories, SERT II.

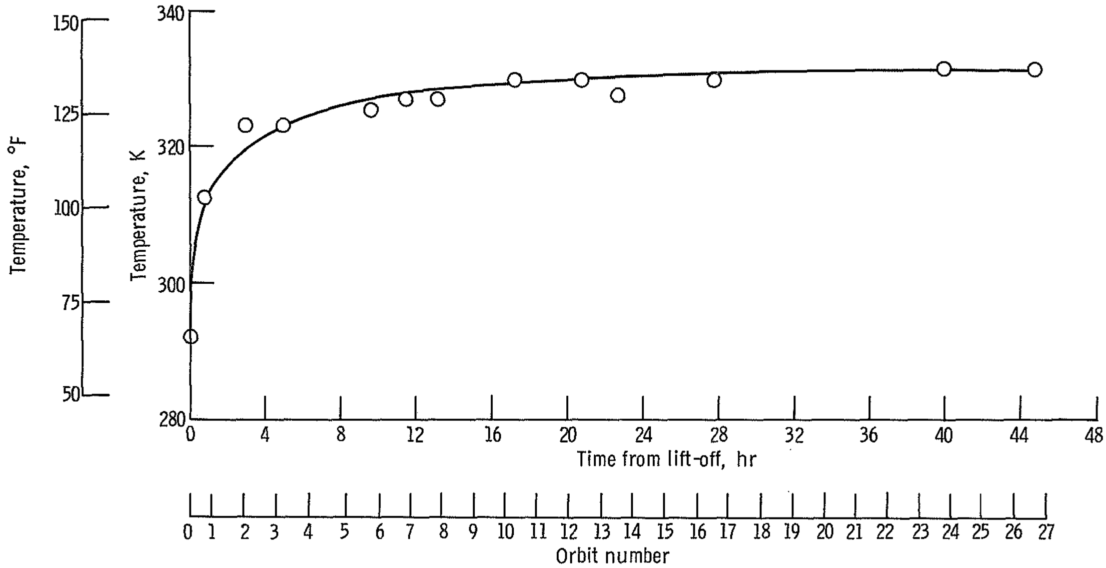


Figure F-3. - Inverter temperature history, SERT II.

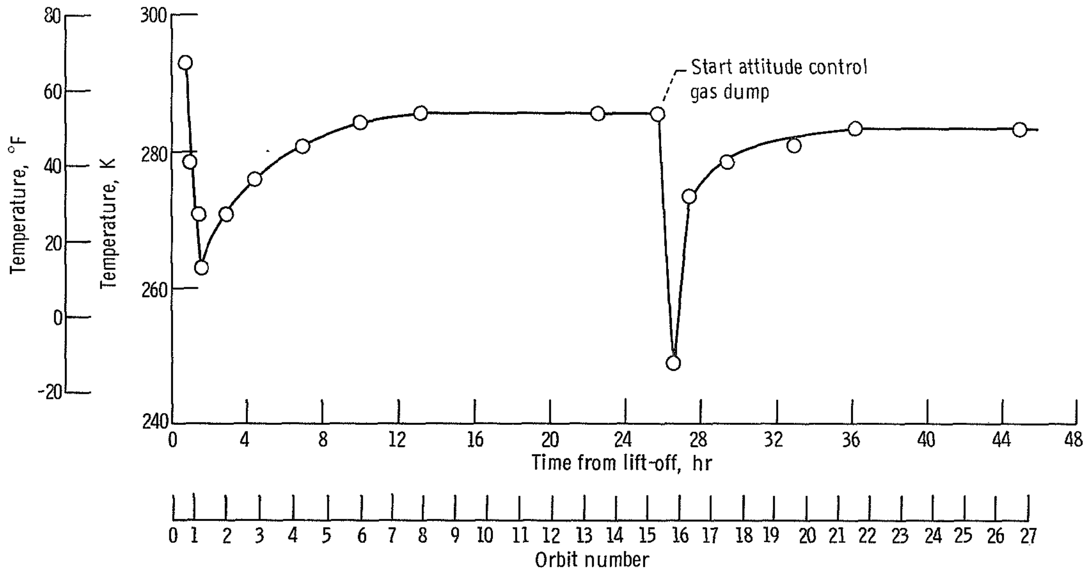


Figure F-4. - Attitude-control-gas-supply temperature history, SERT II.

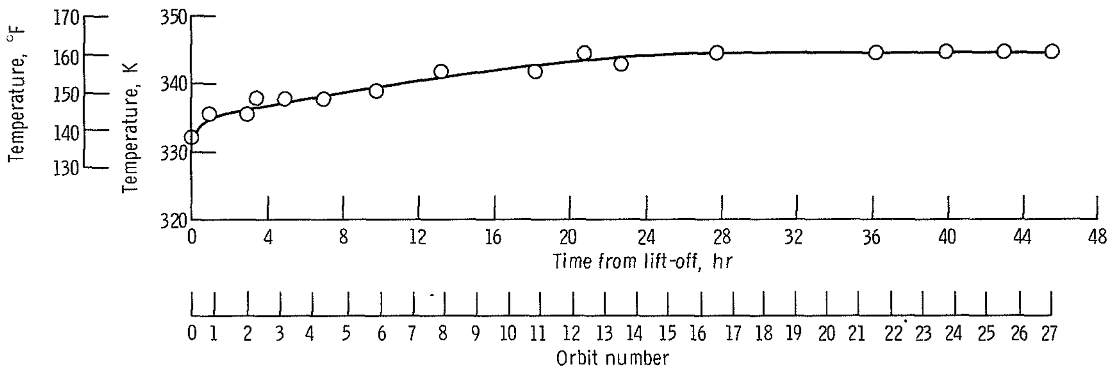


Figure F-5. - Inertial-reference-package temperature history, SERT II.

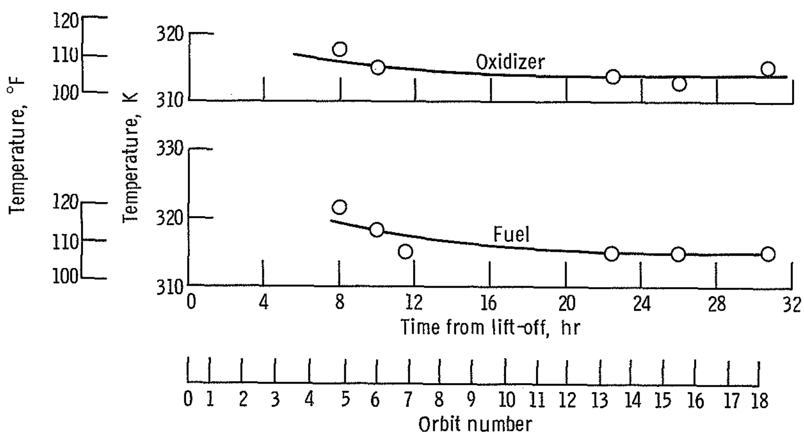


Figure F-6. - Fuel pump and oxidizer pump inlet temperature histories, SERT II.

NASA-Langley, 1971 —— 31 E-5982

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— NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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